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WITH PLATE I.

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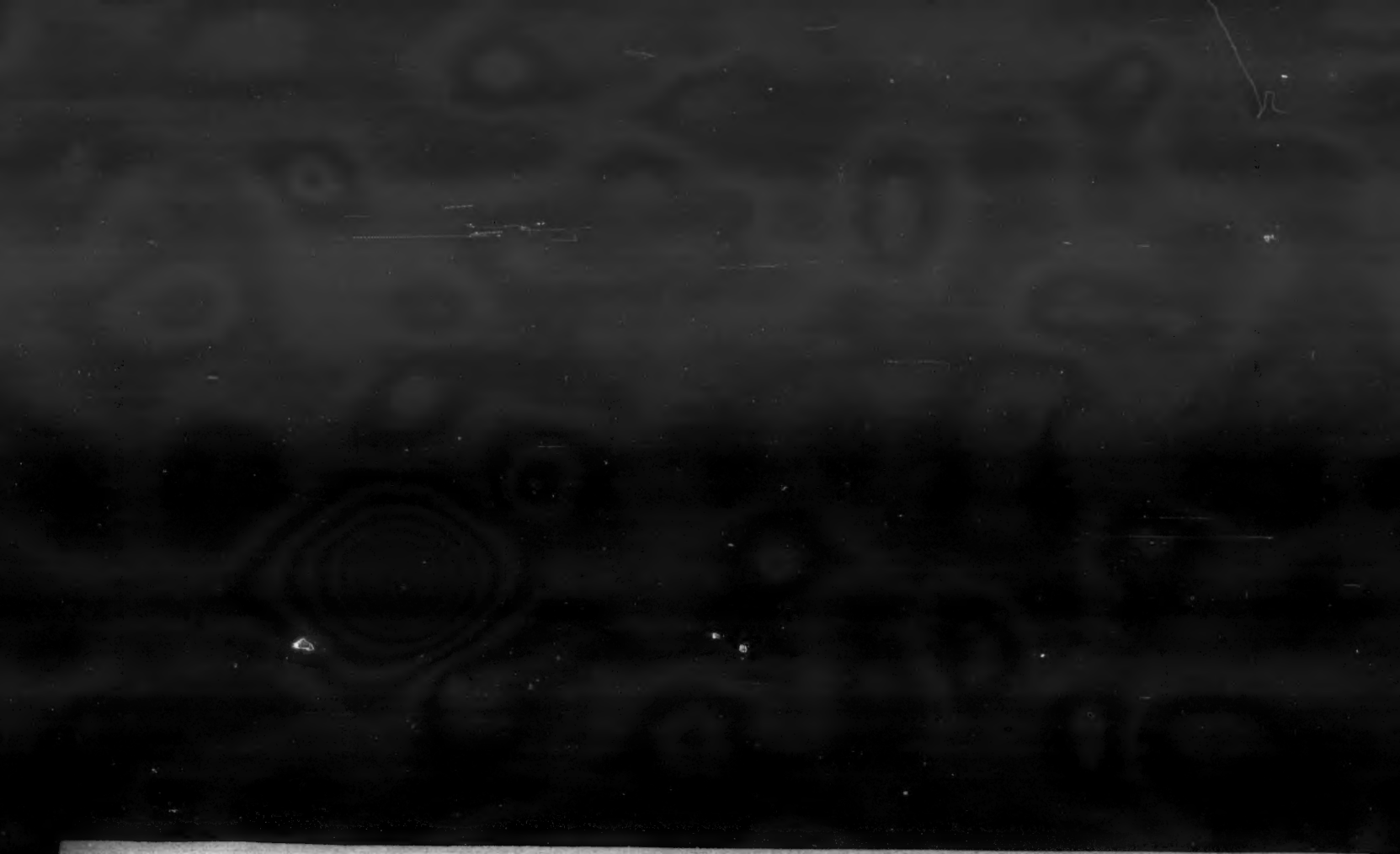
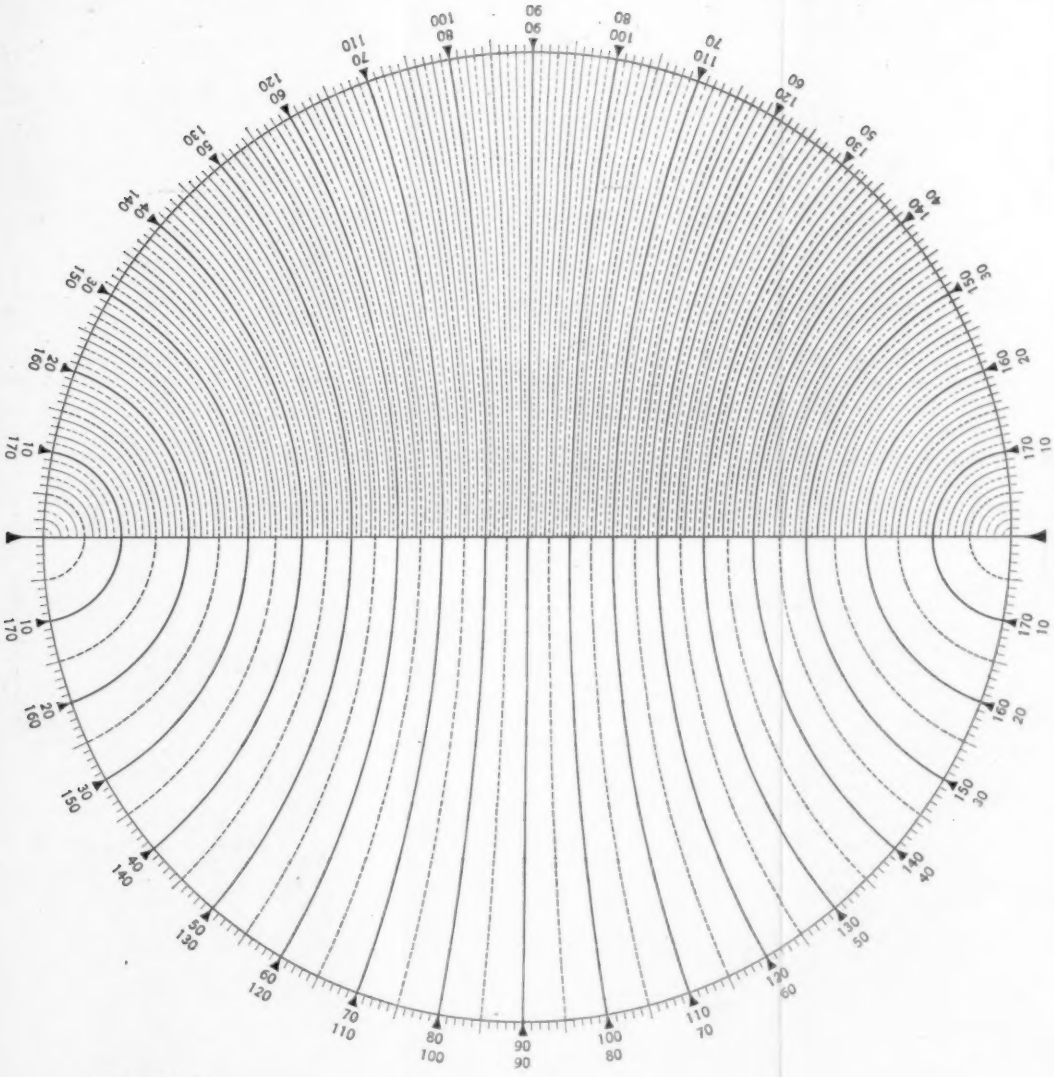


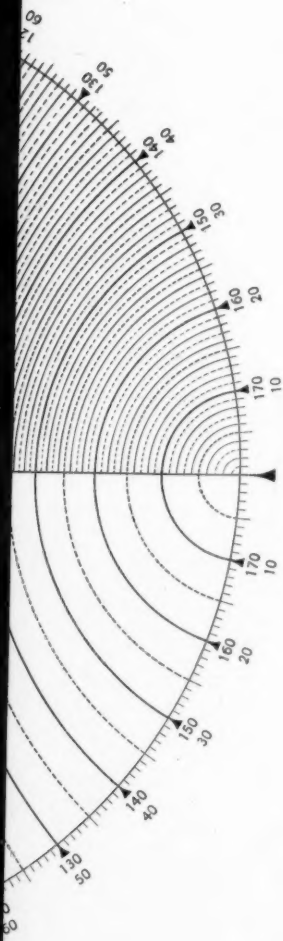


Patent applied for.

STEREOGRAPHIC PROTRACTOR NO. II, FOR MEASURING THE ARCS OF GREAT CIRCLES.

Printed from the original engine-divided plate.

Plate I.



AT CIRCLES.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*The Stereographic Projection and its Possibilities, from a Graphical Standpoint;* by S. L. PENFIELD. (With Plate I.)

Introduction.—The results which are given in the present paper are the outgrowth of a desire on the part of the writer to simplify some of the processes of plotting and determining crystal forms. The whole subject of stereographic projection, as it has gradually unfolded itself to him during the past two years, has revealed so many possibilities, and seems so important and of such general interest, that it has been decided to present first a paper treating of the stereographic projection alone, leaving for a later communication its applications to special problems of crystallography.

As far as the mathematical principles of the projection are concerned, the writer lays claim to no new facts. The projection is treated, in more or less detail (usually very briefly), in most text-books of crystallography, and instructions are given for making stereographic projections. The processes recommended, however, are generally tedious, and one of the objects of the present paper is to indicate how projections may be constructed easily and very accurately. Moreover, no mathematical formulas nor equations have been used in developing the subject, neither have tables been employed other than one of natural tangents for calculating a certain scale. The principles of the projection, as set forth in this article, are absolutely exact; while the errors involved in solving problems by graphical methods are dependent upon one's ability to locate points and read scales correctly, the errors generally diminishing as the size of the projection increases. It is also true of numerical calculations that the processes are limited. Given exact data, results accurate to the minute or to the second are

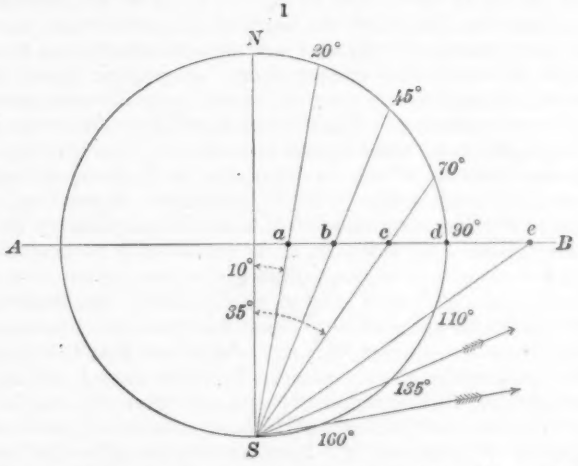
obtained according as four-place or seven-place logarithm tables are employed; while for some very exact geodetic computations, where small fractions of a second must be taken into consideration, ten-place logarithm tables are at times made use of. The advantages of graphical methods over numerical calculations are numerous, and are fully appreciated by engineers and others who deal extensively with measurements and practical results derived therefrom.

The writer would be one of the last to claim that numerical calculations can be dispensed with, yet he contends that, for a large number of problems, especially those where the data are not very exact, results obtained by graphical methods are in every way as serviceable as those secured by calculation. Then, too, it is possible to make computations by graphical methods wholly without the use of formulas and tables, and the processes can be carried out intelligently by persons who have had no special mathematical training, provided only that they have an appreciation of measurements expressed in terms of degrees and fractions. Many advantages to be derived from the use of the stereographic projection will naturally suggest themselves during the course of this paper. In subsequent paragraphs some of these advantages will be set forth, and results obtained by plotting will be given, in order that an idea of the accuracy of the method may be obtained.

General Principles of the Stereographic Projection.—In this method of projection all points and arcs on the surface of a sphere are projected on a flat surface (the plane of the projection) passing through the center of the sphere, the pole or point to which everything is projected being located on the surface of the sphere and at right angles to the plane of the projection. Often the equatorial plane is chosen as the plane of the projection, and the pole to which everything is then projected is the south pole. Under the foregoing conditions, it is also customary to represent only the features of the upper half of the sphere (the northern hemisphere) in the projection, although, as will be shown, the projection may be carried out beyond the equator so as to include the southern hemisphere as well. Projections are likewise frequently made upon a plane passing through some north and south meridian, in which case the pole of the projection will be located upon the equator, at right angles to the plane of the projection. As will be shown, projections can be made without difficulty upon any desired plane. A most important feature of the stereographic projection is that all angular distances and directions, which can be plotted and measured only with difficulty on a spherical surface, appear on the flat surface of the stereographic projection in such relations that they may be easily plotted and measured. This is true of no other method of projection.

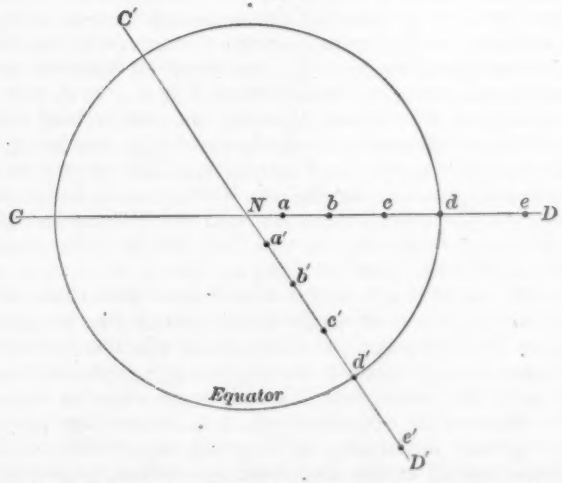
Some essential features of the stereographic projection are illustrated in figure 1. The circle represents a vertical section

1



through a sphere, or a north and south meridian if considered as such. *N* and *S* are the north and south poles, respectively, and *A B* is the trace of the plane of the equator. Points on

2



the meridian 20°, 45°, 70°, and 90° from *N*, when projected to the south pole, are seen upon the plane of the equator at *a*, *b*,

c, and *d*, respectively, while points more than 90° from *N* (110°, 135°, and 160°, for example), when projected to the south pole and continued along the lines of projection until they meet the plane of the equator, appear beyond the circle at *e*, and points still farther out as indicated by the direction of the arrows. In stereographic projection, figure 2, the equator appears as a circle, the north pole *N* occupies a position in the center, and a north and south meridian is projected upon the plane of the equator as a straight line corresponding to some diameter of the circle, it may be *C D*, or it may have some other direction, *C' D'* for example, depending, so to speak, upon the longitude of the meridian. Points 20°, 45°, 70°, 90°, and 110° from *N*, as measured on a north and south meridian, appear in stereographic projection, figure 2, at *a*, *b*, *c*, *d*, and *e*, or *a'*, *b'*, *c'*, *d'*, and *e'*, respectively, the distances of these points from *N* being equal to those of corresponding points from the center, figure 1, provided that the diameters of the two circles are the same. The diameter *C D*, figure 2, represents a stereographically projected north and south meridian, and the distances *N* to *a*, *b*, *c*, *d*, and *e*, indicate 20°, 45°, 70°, 90°, and 110°, respectively, as measured on the meridian. The true linear distances *N* to *a*, *b*, etc., are equal to the tangents of half the angles under consideration, the radius of the circle being regarded as unity. The foregoing tangent relation is well illustrated in figure 1, and depends upon an important principle of geometry; namely, that two lines within a circle meeting at the circumference (as any two lines meeting at *S*, figure 1) make an angle with one another which is measured by half the arc included between the lines at the circumference. The distances *N* to *a*, *c* to *d*, and *d* to *e*, each represent 20° in stereographic projection, and the relations of these distances should be carefully considered. Proceeding from the center, each stereographically projected degree is somewhat greater than the one just before it, hence the distance *c* to *d* just within the equator is nearly twice as great as *N* to *a* near the pole, and *d* to *e* just beyond the equator is more than twice as great as *N* to *a*.

From a consideration of figure 2, it is evident that, although any point on the stereographic projection (*a*, for example) which is 20° from the pole has a fixed relative distance from the center irrespective of the size of the circle, the absolute distance of 20° from the pole will vary with the size of the circle. Hence, the construction of stereographic projections can be greatly facilitated by adopting some definite size for the fundamental circle, and devising certain protractors and scales, by means of which points occupying known positions on the sphere may be quickly and accurately plotted. In

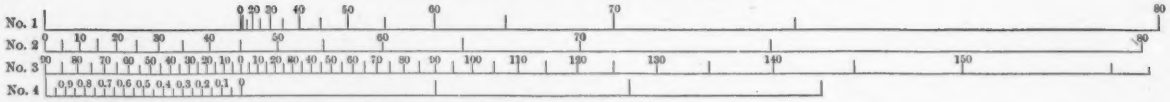
deciding upon an appropriate scale on which to make stereographic projections, it was necessary carefully to consider the two following points:

If the construction is too small, it is difficult to locate given points with sufficient accuracy, by means of a pencil and ordinary drawing instruments; while, on the other hand, if the construction is on too large a scale, the drawing becomes unwieldy and presents many difficulties, although the degree of accuracy is greatly increased. After some experimenting it was decided to make the projections on a circle of 14^{cm} diameter, and after nearly two years' experience, during which time almost all kinds of crystallographic problems have been under consideration, it may be stated that this scale has proved very satisfactory.

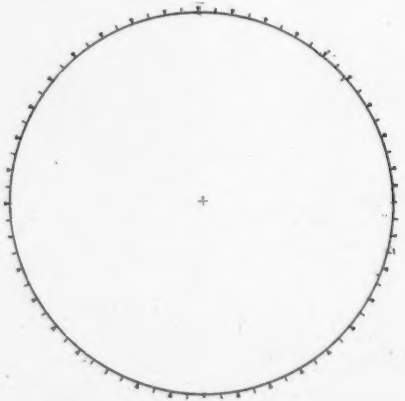
The Graduated Circle.—As one of the first aids for the quick and accurate construction of stereographic projections, a circle of 14^{cm} diameter, graduated into degrees, was engraved. Every tenth degree of the graduation is accentuated, so that it may be quickly caught by the eye, but it was thought best not to number the entire graduation, as degrees can be easily counted off. The exact center of the circle is indicated by a small cross. The circle was engraved by means of a dividing engine, which is equivalent to a guarantee of its accuracy. (See page 23.) The circle and some scales which will be described later are shown, much reduced and with only 5° graduation, in figure 3. They are printed together on large sheets of paper of excellent quality, the idea being that the sheets may be purchased at a trifling expense, and used for plotting all kinds of problems in stereographic projection.

Protractor No. I for plotting Stereographic Projections.—In order to facilitate the work of locating known points on a diameter of the graduated circle, a special protractor, designated as No. I, has been devised, which is shown without reduction in figure 4. The semicircle, divided into degrees, has a diameter of 14^{cm}, thus corresponding to the diameter of the graduated circle, figure 3, of the printed sheets. Holding the protractor in a vertical position, and regarding the upper 0°–90° point of the semicircle as the north pole, lines drawn from degree points on the semicircle to an imaginary south pole would cross the diameter at correspondingly numbered, *stereographically projected*, degree points. The distance from the center to each degree line of the graduation was determined by calculation, and the scale was then engraved by means of a dividing engine. The graduation has been numbered in both directions in order that angles given from either the pole or the equator can be conveniently located. The protractor is printed on cardboard and is inexpensive. It may be

DIVIDED CIRCLE AND SCALES FOR PLOTTING STEREOGRAPHIC PROJECTIONS.

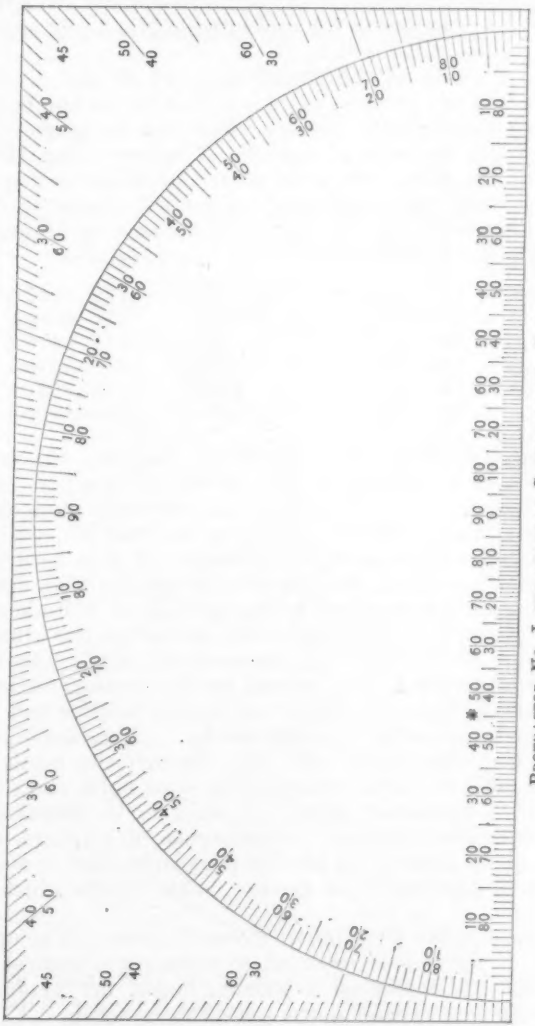


No. 1 Radii of Stereographically projected arcs of great circles, degrees measured from the divided circle.
No. 2 Radii of Stereographically projected arcs of small vertical circles, degrees measured from the divided circle.
No. 3 Degrees of a vertical great circle stereographically projected on a diameter.
No. 4 Decimal parts of the radius of the divided circle.



On the original engine-divided plate the circle has a diameter of 14^{cm} and is divided into degrees (compare plate I). The scales likewise are subdivided so as to give desired parts to degrees.

employed either in semicircular or rectangular form as an ordinary protractor for laying off and measuring plane angles.



PROTRACTOR No. 1, FOR PLOTTING STEREOGRAPHIC PROJECTIONS.
The graduation on the base line gives the stereographically projected degrees.
From * to 0 equals the chord of 90°.
Printed from the original engine-divided plate.

Scale No. 3, accompanying the graduated circle, figure 3, repeats the graduation of the base line of the protractor, and the graduation is further continued for arcs of more than 90°

from the pole. Thus, referring to figures 1 and 2, p. 3, the distances at which the lines of projection of arcs of 110° and 135° would meet the diameter can be taken directly from this scale. Various examples of the uses of scale No. 3 will appear during the course of this article.

Owing to the size of the sheets upon which the divided circle and scales are printed, there is a limit to the number of stereographically projected degrees which can be given. As seen in figure 3, the end of scale No. 3 indicates the 156th degree from the pole. Since in some operations it may be necessary to carry the projection beyond the limits of this scale, the distances from the pole to the remaining projected degrees are given in millimeters in the following table:

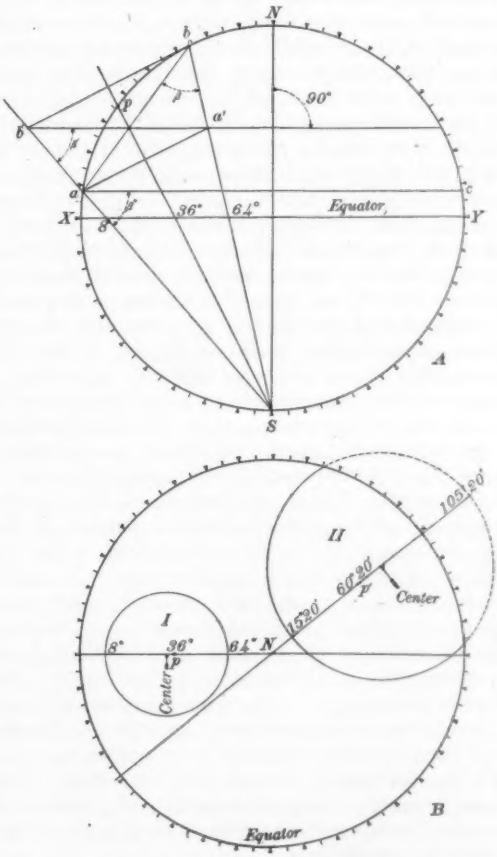
157°–344·1mm	163°–468·4mm	169°–727·0mm	175°–1603·3mm
158 –360·1	164 –498·1	170 –800·1	176 –2004·5
159 –377·7	165 –531·7	171 – 889·4	177 –2673·2
160 –397·0	166 –570·1	172 –1001·0	178 –4010·3
161 –418·3	167 –614·4	173 –1144·5	179 –8021·2
162 –442·0	168 –666·0	174 –1335·7	180 Infinity

The Possible Circles on a Spherical Surface.—About a point p located anywhere on the surface of a sphere, two kinds of circles may be described; an indefinite number of *small circles*, whose distance from p is less than 90°, and one great circle, at a distance of 90° from p. If p is located at either the north or the south pole of a sphere, the small circles described about p correspond to the parallels of latitude of a terrestrial globe, and the great circle answers to the equator. If the sphere is oriented with its north and south poles in a vertical direction, and p is located on the equator, the small circles described about p will have a vertical position and will be referred to as *vertical small circles*. A *vertical great circle*, on the other hand, will pass through the north and south poles, and will thus correspond to some north and south meridian of a terrestrial globe. A great circle, whatever its position, corresponds to some circumference of a sphere, and, moreover, every great circle has this peculiarity, that it crosses the horizontal great circle, or equator, at two points which are antipodal.

The Stereographic Projection of Small Circles.—The upper portion A of figure 5 is intended to represent a vertical section through the center of a sphere; hence, the graduated circle corresponds to some north and south meridian. $X\ Y$ is the trace of the plane of the equator, and N and S are the north and south poles, respectively; p is some fixed point on the meridian, the figure representing it as 36° north of the equator. Around p, a small circle is supposed to be described,

every point of which is $x°$ from p. In the figure, x is equal to 28°, hence the circle touches the north and south meridian at the points a and b, respectively at 8°, $=36°-28°$, and 64°, $=36°+28°$. It is evident that all possible lines of projection

5, *A* and *B*.



running from S to the small circle under consideration must be located upon the surface of an imaginary cone, with its apex at S and having a circular base touching the meridian at a and b. Such a cone is an *oblique cone*, and the plane $a\,b\,S$ is a symmetrical section through it. Continuing the line $S\,a$, laying off a distance $S\,b' = S\,b$, and joining $b\,b'$, a section $b\,b'$

through the cone will be an ellipse, but it is not necessary for the present discussion to demonstrate this point. A line joining the center of $b\,b'$ and S, passes through p, bisects the angle of the cone at S, and may be regarded as an axis of the cone. Let it now be imagined that the cone $b\,b'\,S$ revolves about the axis $S\,p$. Since the section $b\,b'$ is an ellipse, and an ellipse is a figure of binary symmetry, the surface of the cone during the first quarter of the revolution will depart somewhat from its original position, and then on continued turning it will approach more and more to its original position until a revolution of 180° has been accomplished, when the correspondence of the conical surfaces will be complete. After the revolution of 180°, the points a and b of the cone in its original position will be transferred to a' and b', respectively, and the section $a'\,b'$ must be a circle, because $a\,b$ was a circle. Figure 5, *A*, illustrates a most important feature of the stereographic projection; namely, *that no matter where p is located, if the pole of the projection is at S, all circular sections corresponding to a' b' are horizontal and parallel to the plane of the equator; hence, the lines of projection running from S to the circle a b or a' b' intersect the plane of the equator in a circle.* Proof of this feature of the stereographic projection is very simple. The angles β and β', figure 5, *A*, are equal, because they belong to the same cone before and after a revolution of 180° about the axis $S\,p$. Draw the line $a\,c$ parallel to $b'\,a'$, and β'' will equal β' because of the construction. The angle β (on the circumference of the circle at b) is measured by half the arc $S\,a$, and the angle β'' is measured by half the arc $S\,c$; therefore, since β and β'' are equal, the arcs $S\,a$ and $S\,c$ are equal. This being true $a\,c$ must be a chord, at right angles to a line joining the north and south poles, and hence *horizontal*, or parallel with the trace of the equator $X\,Y$. What holds good for a circle cutting the meridian at the points a and b, figure 5, A, holds good for a circle in any possible position on the sphere; hence, *all circles on the sphere will appear in stereographic projection as circles on the plane of the projection.*

Figure 5, *A*, further illustrates an interesting feature of conic sections; namely, that through an oblique cone circular sections are possible in two directions,—parallel to $a\,b$ and $a'\,b'$. All other sections are ellipses.

The construction of a small circle in stereographic projection corresponding to the problem of which, so to speak, an elevation has just been given in figure 5, *A*, becomes a very simple matter, and is illustrated in figure 5, *B*, case *I*. The divided circle here corresponds to the equator, and the north pole N is in the center. A north and south meridian would appear in the projection as a diameter of the circle, and the

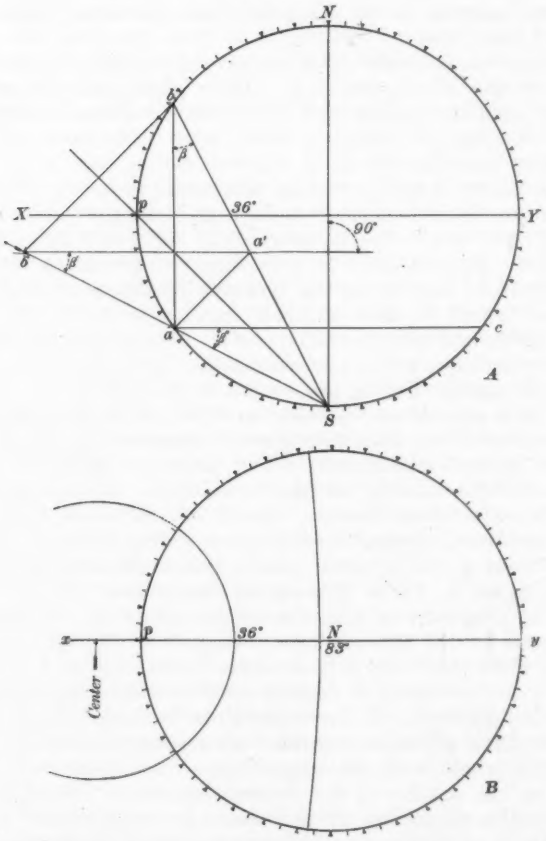
pole p, 36° from the equator, is readily located on a diameter by means of protractor No. I, p. 7. On just what diameter it should be placed would depend upon some determining factor—for example, the longitude of the meridian. The small circle which is to be projected is $x° = 28°$ from p; hence it would intersect the north and south meridian at points 8° and 64° from the equator, which points can be quickly located on the same diameter as p by means of protractor No. I. All that now remains to be done is to find the center point and construct the circle.

Another small circle in stereographic projection is illustrated by case II, figure 5, *B*. Here p' is some pole which may be located anywhere within the circle. Draw a diameter passing through p', bring the base line of protractor No. I to correspond with the diameter, and note the position of p'. In the case under consideration, p' was found to be 60° 20′ from *N*. The small circle described about p' is distant 45° from p'; hence it will touch the diameter at 15° 20′ = 60° 20′ − 45° 0′, and at 105° 20′ = 60° 20′ + 45° 0′. The two points 15° 20′ and 105° 20′ can be located on the diameter by means of scale No. 3, figure 3, and it then becomes an easy matter to find the center point and construct the circle. Numerous applications of the principles of the stereographic projection of small circles will appear during the course of this article.

The Stereographic Projection of Vertical Small Circles.—This is a problem deserving special consideration because of its very general application. The point p, figure 6, *A*, is located on the equator at the crossing of some meridian; hence the small circle described about it touches the north and south meridians, passing through p at points a and b, equally distant from p. The same demonstration that was employed on p. 9, figure 5, *A*, for illustrating that a small circle on the sphere is projected as a circle on the plane of the equator, holds good in the present case. Figures 5, *A*, and 6, *A*, are lettered alike, and the demonstration need not be repeated. In order to construct a vertical small circle in stereographic projection, figure 6, *B*, four points can be readily fixed upon. Two of these are the projection upon some diameter, $x\,y$, of the points a and b of the upper figure, the other two being points on the equator at the desired distance, $x°$, from p. To facilitate the projection of any desired vertical small circle, scale No. 2 of figure 3 has been constructed, from which the radius of the desired circle can be obtained. To construct, therefore, a small circle 36° from p, as represented by figure 6, *B*, draw a diameter $x\,y$ through p, and upon it, by means of the scale on the base line of protractor No. I, locate a point 36° from p. Then set a pair of dividers so that their points

will span the distance from 0° to 36° on scale No. 2, figure 3, find the center point on the diameter $x\ y$, and draw the small circle, which will intersect the divided circle at 36° from p. Owing to the character of the stereographic projection, the greater part of projected vertical circles will always lie outside the divided circle.

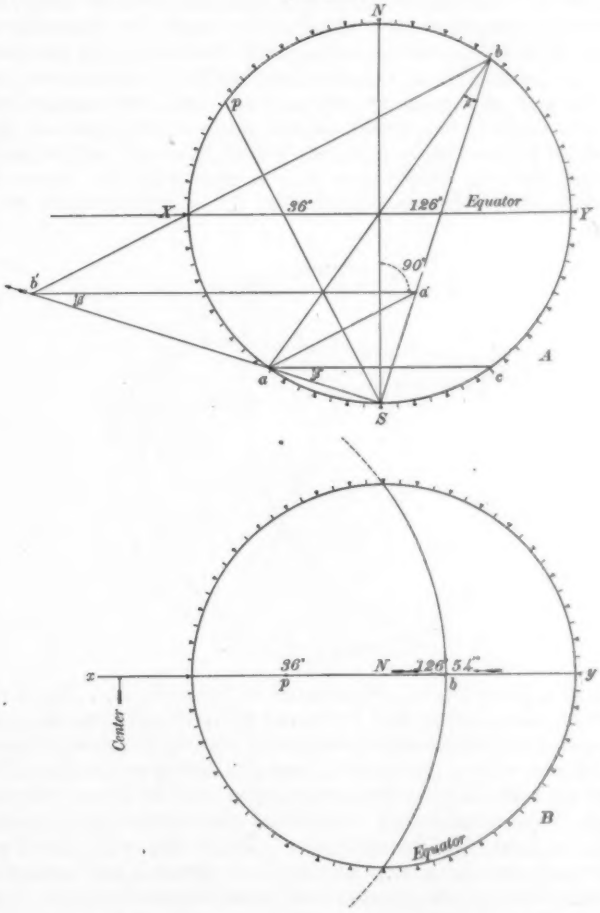
6, *A* and *B*.



Vertical circles nearly 90° from p have very long radii, and are best constructed by means of the curved ruler described later on. Thus, a vertical circle 83° from p, figure 6, *B*, must pass through two points 83° from p on the divided circle,

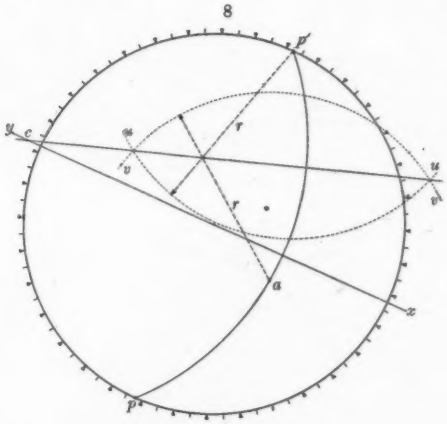
and also through the stereographically projected 83° point, as plotted on the diameter $x\ y$, by means of the graduation on the base line of protractor No. I.

7, *A* and *B*.



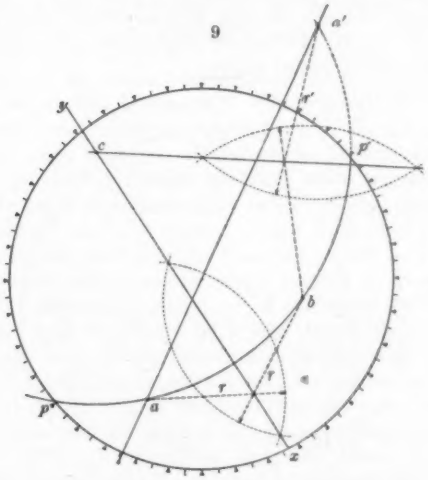
The Stereographic Projection of Great Circles.—What was true of a small circle described about some point p as a center, holds true also for a great circle intersecting a north and south meridian, figure 7, *A*, at points a and b, 90° from p. In the special case illustrated by the figure, p being 36° from the

equator, the line of projection from S to b crosses the plane of the equator at 126° (stereographically projected) from the left-hand end of the diameter XY, or 54° from the right-hand end, while the line of projection from S to a would intersect the plane of the equator far out beyond the divided circle, as indicated by the arrow, at a point which could be determined by scale No. 3, figure 3, a being 144° from N. All possible lines of projection from S to the great circle $a\ b$ are located on the surface of an imaginary oblique cone with its apex at S. Moreover, it could be proved, as was done in the case of the small circle illustrated by figure 5, A (the figures being lettered the same), that the intersection of the cone with the plane of the equator is in this case also a circle. The stereographic pro-



jection of a great circle is illustrated in figure 7, B. The projection of the point b, 54° from the equator on a north and south meridian, as shown by the upper figure, is quickly found on the diameter $x\ y$ by means of the graduation on the base line of protractor No. 1. A circular arc must then be found passing through b, and intersecting the divided circle at antipodal points at right angles to the diameter $x\ y$. To facilitate the construction of such circular arcs, scale No. 1 of figure 3 has been constructed, which gives the radii of possible great circles. As the arcs of projected great circles approach N (the center of the divided circle) they become flatter; hence they are best constructed by means of the curved ruler described later on. As seen from scale No. 1, figure 3, the shortest radius of any stereographically projected great circle is equal to the radius of the divided circle.

To draw the projected arc of a great circle through two points, one of which, *p*, figure 8, is on the divided circle and the other, *a*, within the circle, is a simple matter. The circular arc must intersect the divided circle at *p'*, antipodal to *p*, and its center must be on a line *x y* intersecting the divided circle at 90° from *p* and *p'*. The center *c* may be found by a few trials with a pair of dividers, or it may be determined analytically as follows: With dividers opened up to some convenient distance construct two circular arcs *u u* and *v v*, figure 8, having the same radius *r*, and draw a line through their intersections. The line thus drawn will be at right angles to the cen-

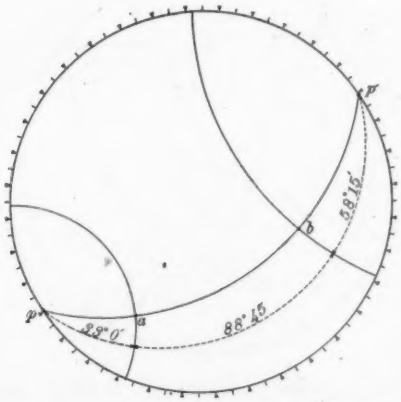


ter point of a line joining *a* and *p'*, and will intersect the line *x y* at *c*, which will be the center of the circular arc *p a p'*.

To draw the projected arc of a great circle through two points *a* and *b*, both of which are within the divided circle, the following principles may be used: That the great circle passing through *a* and *b* must also pass through points *a'* and *b'*, antipodal, respectively, to *a* and *b*; also that the great circle must intersect the divided circle at antipodal points *p* and *p'*. If, therefore, there are two points, *a* and *b*, figure 9, anywhere within the circle, draw a diameter through one of them, *a* for example, and continue it beyond the circle. Apply the base line of protractor No. I to the diameter, determine the distance, in stereographically projected degrees, of *a* from the divided circle, and, making use of scale No. 3, figure 3, locate

a' just as many projected degrees beyond the divided circle as a is within it. Thus, as measured on a stereographically projected north and south meridian, a' is antipodal to a, and the problem of finding the center c and drawing a circular arc through a, b, and a', which is fully illustrated by the figure, is too simple to need more detailed explanation. In some cases it may prove easier to plot a line $x\ y$, as illustrated by figure 9, and find upon it the point c by trial, for only one circular arc can be found, which, passing through a and b, intersects the divided circle at antipodal points p and p'. If the two points within the circle are so located that the projected great circle passing through them has a very long radius, the curved ruler described later on can be quickly adjusted so that a circular arc may be drawn passing through them and intersecting the divided circle at antipodal points.

10



To measure the Angular Distance between any two points on a Stereographic Projection.—To measure the Side of a Spherical Triangle.—Let the two points a and b, be anywhere within the divided circle, figure 10. Since the angular distance between any two points on a sphere is measured in degrees along the arc of a great circle, it is first necessary to construct a great circle passing through a and b, and thus locate the antipodal points p and p' on the divided circle. It is now possible to find some projected vertical small circle described about p, which passes through a and serves as a measure of the angular distance p to a; likewise a small circle described about p' and passing through b, which serves to measure the distance from p' to b. Knowing the angular distances p to a and p' to b, the distance a to b is readily determined. In fig-

ure 10, p to $a = 33°\ 0'$ and p' to $b = 58°\ 15'$; hence a to $b = 88°\ 45'$, or the supplement of the sum of the two angles.

Without the aid of the special protractor described in the next paragraph, it is a laborious task to find the two projected vertical circles passing through a and b, figure 10; though by making use of the protractor No. I and scale No. 2, figure 3, they can be plotted without great difficulty.

Stereographic Protractor No. II.—To facilitate measurements of the angular distances between points on a stereographic projection, or measurements of the sides of spherical triangles, a special protractor has been devised which is represented in plate I, without reduction, and will be designated as the *Stereographic Protractor*, or *Protractor No. II.* The essential features of this protractor are as follows: The circle of 14^{cm} diameter, divided into degrees, corresponds with the divided circle shown, much reduced, in figure 3. On one-half of the circle, the projected arcs of vertical small circles, p. 11, have been constructed for every degree. Since on a 14^{cm}-circle the stereographically projected circles are very near together, the even degrees have been represented by full lines and the odd degrees by dashed lines; also the arcs of every fifth and tenth degree are engraved somewhat heavier than the others. These details, however, are not essential, but simply serve to make the use of the protractor somewhat easier. On the other half of the circle only the arcs of every fifth and tenth degree are represented. This half of the protracter is really superfluous, but for approximate measurements it will at times be found more convenient than the other half where the arcs are crowded. For convenience the protractor is numbered in two directions, from 0° to 180°. Further, in order to have the protractor really practical, it should be printed or engraved on some transparent material; transparent celluloid has been found to satisfy every requirement.

To use the protractor in finding the distance from a to b, figure 10, for example, lay it (best with the printed side down) on the drawing, and bring the 0° and 180° points to correspond with the antipodal points p and p' on the divided circle, then note the distances p to a and p to b in degrees and fractions, and the difference between the two readings will equal the angular distance from a to b.

To measure from any given point p on the divided circle to a point a within the circle, it is not necessary to go through the operation of constructing the arc of a great circle through p and a, as represented in figure 8, p. 14; merely place the protractor with its 0° and 180° points on p and p', and then note on the protractor the projected arc which corresponds most nearly to a.

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To measure the Angle made by the meeting of Two Great Circles.—To measure the Angle of a Spherical Triangle.— Just as the angle between two meridians at the north pole of a sphere is measured on the equator, so the angle between two great circles crossing at a point A, which may be anywhere within the divided circle, figure 11, is measured on the arc of a great circle at 90° from A. To make the measurement of the angle, draw a diameter of the divided circle through A, and, applying the base line of protractor No. I to the diameter, note the distance in projected degrees from N to A; then locate a point B just as many degrees from the divided circle as A is from N. A and B are thus 90° apart, and, making use of

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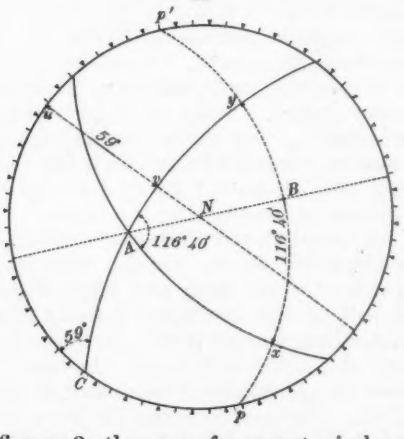


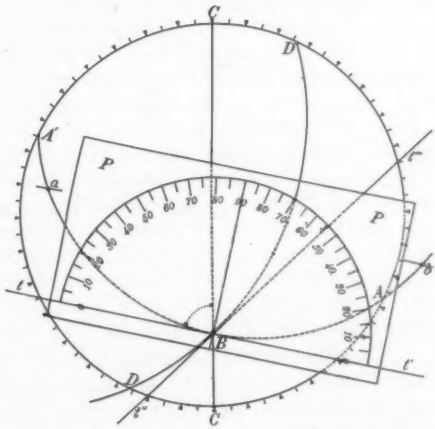
scale No. 1, figure 3, the arc of a great circle $p\ p'$, passing through B, can be easily drawn. All points on the great circle thus plotted, including the intersections x and y, are 90° from A, and the angle at A is equal to the distance in projected degrees between x and y, as measured with the stereographic protractor on the arc of the great circle $p\ p'$.

Provided an angle is located on the divided circle, as at C, all that is necessary to do is to draw a diameter of the divided circle at 90° from C, and measure the angle at C on the projected north and south meridian by means of the graduation on the base line of protractor No. I; for example, from u to $v = 59°$.

Another method of measuring the angles of spherical triangles depends upon a well known and interesting peculiarity of the stereographic projection, to which the writer's attention was called by Prof. G. P. Starkweather of Yale University; namely, *that the angle made by the crossing of two circles on*

a sphere is preserved in the stereographic projection of the circles. The method of measuring is illustrated by figure 12. ABC is a right spherical triangle, and to measure the angle B, draw through B a tangent tt'; the angle formed by tt' and the diameter CC' determines B. To draw accurately the tangent tt', locate two points a and b, equally distant from B, on the great circle ABA'. A line joining ab would be a chord of the circular arc ABA', and a line through B, parallel to ab, is a tangent to the circle. An ordinary protractor PP, preferably a transparent one,* centered at B by means of

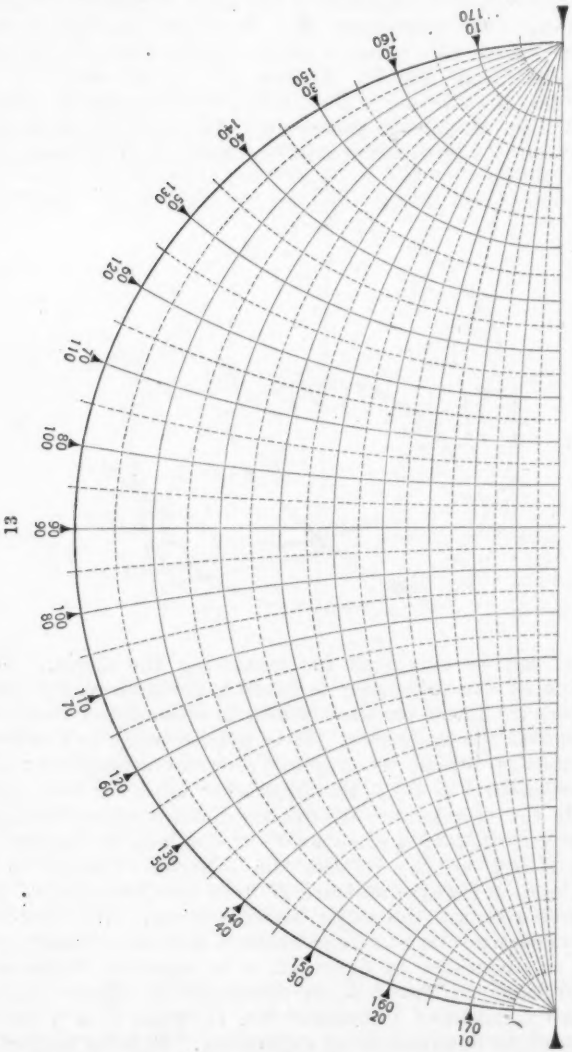
12



a needle, can be employed for measuring the angle. The 0°–0° line of the protractor is made to coincide with tt', and the angle (78° 15′ in the illustration) is determined from the graduation of the protractor. It is not necessary to construct the tangent tt' except when great accuracy is required; it is simply necessary to turn the protractor until the arc ABC intersects the circular arc of the protractor at equal distances from its two 0° points when its 0°–0° line will be tangent to the arc ABA' at B. In case the spherical triangle is an oblique one, ABD, to measure B draw two tangents, tt' and $t''t'''$, then measure the angle between them. Whether it is easier to construct tangents and measure with an ordinary protractor, as illustrated by figure 12, or to construct the arc of a great circle at 90° from B, as illustrated by figure 11, and measure by means of protractor No. II, plate I, is a matter which must be determined by experience. It is far simpler to

* Protractor No. II, plate I, which is printed on transparent celluloid and is divided at the periphery into degrees, can be employed.

measure the angles *A* and *D*, figure 12, by means of the graduation on the base line of protractor No. I, page 7, than by constructing tangents and measuring the plane angles.


13
Patent applied for.
Stereographic Protractor No. III, with great and small circles for every fifth degree only.
Printed from the original engine-divided plate.

Supplementary Protractors.—Equipped with sheets containing the divided circle and scales, figure 3, and with protractors

I and II, figure 4 and plate I, practically all kinds of problems in spherical trigonometry can be plotted and solved by graphical methods. Two additional protractors, however, are so convenient that some space may be well devoted to them.

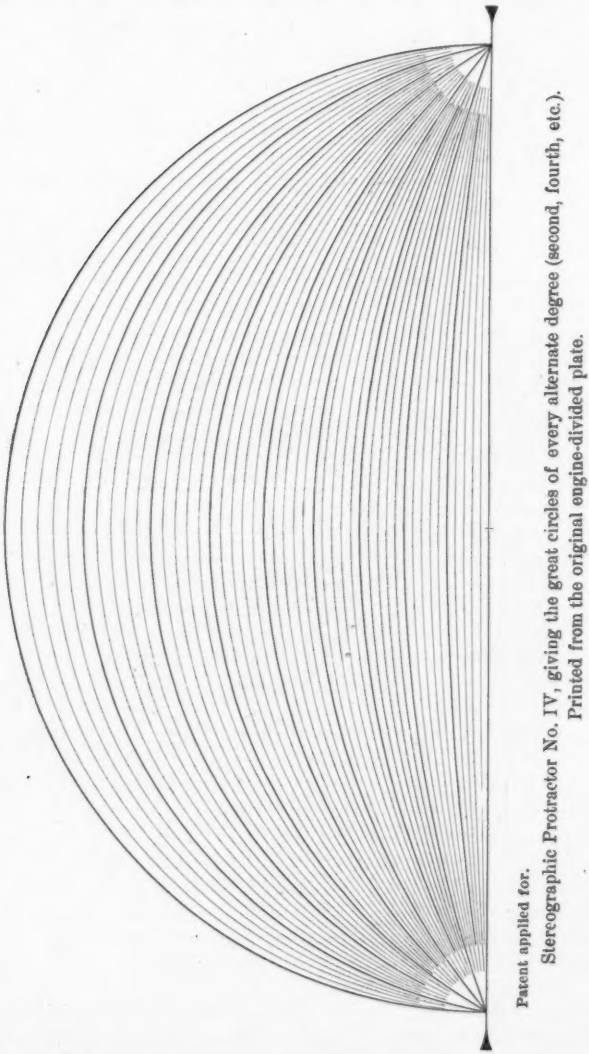
Protractor No. III, figure 13, is a combination of great and small circles on the same sheet. Every fifth degree only is given, the even degrees being indicated by full, and the odd degrees by dashed, lines. It is printed on transparent celluloid and is intended to be used for making an approximate measurement of the distance between any two points on a stereographic projection. At the center, there is a small hole, and if a sheet upon which a stereographic projection has been made is pierced at its center, the protractor can be quickly centered upon the sheet by means of a needle passed through the two holes. Thus centered, the protractor is turned until the two points, the distance between which is to be measured, fall either on an arc of a great circle or at proportionately equal distances between the arcs of two great circles. The distances of the two points from either zero point of the protractor is then noted, as indicated in degrees by the stereographically projected small circles, and the difference gives the distance between the points. Generally speaking, it is not essential to know upon what great circle the two points are located. They must be on some great circle, and the 0° and 180° points of the protractor locate approximately where this great circle intersects the divided circle. It is from the antipodal points thus ascertained that the readings of the protractor are made.

Given a chart or map in stereographic projection and a protractor, as just described, less than two minutes are required to shift the protractor to the proper position and measure the distance between any two points. Measurements thus made with a protractor graduated only to every fifth degree can be regarded as but approximately correct. They will seldom be more than a degree from the truth, and will average less than half a degree. For quick and approximate work, therefore, this protractor will be very serviceable.

The great circles for every fifth degree might well appear on that half of protractor No. II, plate I, on which the small circles for every fifth degree are engraved. The advantage, however, of having the two kinds of circles on the same protractor was not appreciated until after the plate for protractor No. II had been engraved.

Protractor No. IV.—In this protractor, figure 14, the great circles of every alternate degree (second, fourth, etc.) are represented. On the small scale adopted, it would bring the arcs too close together to represent every degree. The arcs are not numbered, but those corresponding to every tenth degree are represented by lines heavier than the rest, so that they may be

readily caught by the eye. The protractor is printed on transparent celluloid. At the center there is a small hole, and at


14
Patent applied for.
Stereographic Protractor No. IV, giving the great circles of every alternate degree (second, fourth, etc.).
Printed from the original engine-divided plate.

the ends of the semicircle the celluloid is cut away to the exact line of the diameter. The chief use of this protractor is to find the great circle which passes through any two given points

of a stereographic projection; more especially, however, to locate the antipodal points where the great circle crosses the divided circle. To perform this operation, the protractor is centered by means of a needle over a sheet upon which a stereographic projection has been made. It is then revolved until any two points of the projection are on, or proportionately distant from, the same great circle, when, by means of a pencil, marks are made on the drawing where the base line of the protractor crosses the divided circle. From the antipodal points thus located, measurements to the two points within the circle can be made by means of protractor No. II. In the majority of cases it is not necessary to draw the arc of a great circle passing through two points within the circle. To measure the distance between them, however, it is necessary to locate the antipodal points on the engraved circle. On page 15, figure 9, it was shown how a great circle passing through any two points within the circle of a stereographic projection may be plotted. Protractor No. IV furnishes a quick, though perhaps not quite so accurate a method of accomplishing the same result.

The Engraving of the Scales and Protractors.—It seems best to give a brief account of the methods employed in making the scales and protractors. The graduation of scale No. 3, figure 3, repeated in part on the base line of protractor No. I, figure 4, was calculated to a fraction of a millimeter by means of a simple tangent relation; for example, the distance of the 20° line from the center equals the radius of the circle multiplied by the natural tangent of 10°, page 4. The method of preparing scale No. 1, figure 3, may be illustrated by referring to figure 7, *A*, page 13. The distances (from the center) of the stereographically projected 126° point to the right and of the 144° point to the left, as determined by scale No. 3, are added, and their sum divided by two gives the radius of the great circle under consideration. Figure 6, *A*, page 12, illustrates how scale No. 2, figure 3, was derived from scale No. 3. From the distance (from the center) of the stereographically projected 126° point, that of the 36° point was subtracted, and the difference divided by two gives the radius of the small circle under consideration.

Scale No. 4 is not employed in the stereographic projection, but is used in crystallography. The data supplied for making scales 1, 2, and 3 was employed in the construction of the protractors. Scales and protractors were laid out and engraved by means of a dividing engine. The plates were made by the so-called wax process. In this process, a metal plate, covered with a wax preparation, is employed, and the engraving tools cut through the wax to the metal. Engine work on wax plates

should leave the engraver's hands practically perfect. An electrotype of the plates is next taken, and the copper depositing in the grooves made by the engraver's tools furnishes the relief from which impressions are taken. Finally, in order to prepare the electrotype for printing, the copper, stripped from the plate, is strengthened by casting some easily fusible metal upon the back of the electrotype. This casting causes a slight shrinkage of the plates, amounting to about $0{\cdot}5^{mm}$ for a distance of 140^{mm} (the diameter of the protractors). It has been ascertained that the shrinkage is practically uniform and proportional in all the plates, so that no appreciable errors can arise from using engravings of this kind. Still, the plates are not absolutely perfect.

Copper or steel engravings would be preferable to engravings made by the wax process, but both the plates and impressions therefrom would be more expensive. If it is thought best to have another set of scales and protractors on a larger scale, the desirability of having them engraved on steel or copper should be carefully considered. Even impressions made from steel engravings might not be absolutely perfect, for paper changes somewhat under varying climatic conditions, and expansion and contraction are not always alike in every direction.

Another thing to be considered is that celluloid shrinks, and protractors printed from accurately engraved plates may become inaccurate in a few months. Except for its tendency to shrink, however, celluloid is exactly the kind of transparent material upon which to print the protractors, and a very simple correction serves to offset the slight shrinkage. For example, some impressions of protractor No. II, printed on newly purchased celluloid five months prior to the time of writing, have shrunk so that with a zero point of the protractor matched exactly at one end of a diameter of the divided circle, figure 3, the 180° point falls one-half a degree short of coincidence with the opposite end of the diameter. In other words, a distance of 179° 30′, stereographically projected upon a diameter of one of the engraved sheets, figure 3, is measured as 180° by means of the protractor; hence, from measurements made by the protractor, 5′ should be deducted for every 30°, equivalent to 30′ for 180°. It is believed that, in time, celluloid will become seasoned, so to speak, and that it will cease to shrink. Accordingly a rather large stock of this material has been purchased with the hope that in the course of a year or two it will be possible to print protractors which will not change.

Taking into consideration all imperfections of the plates, especially those due to shrinkage in casting, errors arising therefrom are quite insignificant when compared with the errors involved in plotting points and constructing arcs when the construction is based upon so small a scale as a 14^{cm} circle.

(*To be continued.*)

Art. II.—*On the Mode of Occurrence of Topaz near Ouro Preto, Brazil;* by Orville A. Derby.

The current treatises on mineralogy, in the brief reference to the association of the yellow Brazilian topaz of the Ouro Preto district with talcose or chlorite schist, give an idea of a mode of occurrence quite different from that of any of the other known localities of the mineral. This statement is made on the authority of Eschwege, who in the early part of the century (1811–1822) spent a number of years at Ouro Preto and was very familiar with the mines during a period of active working. A fuller statement of Eschwege's observations, given in various writings, but most fully in his Pluto Brasiliensis published in 1833, is as follows. The topaz occurs in a narrow belt of country only a few hundred meters wide, extending for several kilometers from Saramenha, a suburb of Ouro Preto westward, in a nearly straight line for a distance of about 20 kilometers, by the mines of Boa Vista and José Correia to Capão de Lana,* with indications of a second less important belt a few kilometers to the northward. The topaz here occurs *in situ* and exclusively of a yellowish or rose color in contradistinction to the northern region near Minas Novas on the Jequitinhenha, where only white and blue stones occur exclusively in the state of rolled pebbles. The mineral, associated with quartz, specular iron, rutile and euclase, occurs in layers and nests of a fine scaly friable lithomarge, white or colored by iron oxide, all of these minerals being well crystallized but invariably broken at the base and irregularly mingled, as if kneaded into the lithomarge. The topaz-bearing nests and layers are enclosed in a decomposed unctuous schist which provisionally was called talc or chlorite schist, and which in turn are intercalated in the decomposed argillaceous schists of the region that were referred to the primary formation.

Mawe,† and Spix and Martius,‡ who visited the region about the same time gave descriptions of the mines in substantial accord with that of Eschwege, except that they refer the topaz to veins and the latter authors contest the classification of the enclosing schist as talcose, calling its characteristic mineral a modified mica.

No additional information of value regarding the topaz was given until 1882, when Gorceix§ described the principal mines

* Not Ulana nor Lane, as frequently given. Capão is the Indian name for an isolated group of trees or grove and Lana is probably the name of a former proprietor.

† Travels in the Interior of Brazil. London, 1812.

‡ Reise in Brasilien, Munich, 1831.

§ Annaes da Escola de Minas de Ouro Preto, No. 1.

and made analyses (reproduced in full in No. 57 of this Journal) proving that a great part at least of the unctuous schists of the region called talcose or chloritic by Eschwege and others are relatively poor in magnesia and rich in alkalies and are therefore essentially micaceous. Three of the schists analyzed were from the topaz mine of Boa Vista or its immediate vicinity, but it is almost certain that they represent what Eschwege called argillaceous schist (fibrous schist of Gorceix) rather than the topaz-bearing layers themselves, which are nowhere found in a sufficiently sound state to give satisfactory analyses. The lithomarge accompanying the topaz was also analyzed, giving: SiO_2 46·6 per cent, Al_2O_3 38 per cent, MgO 1 per cent, and loss on ignition 14·1 per cent—which is the composition of a true kaolin with a slight percentage of magnesia. The lithomarge is spoken of in one place as occurring in a vein occupying a line of fracture but in another as resulting from an alteration of the schist. The alignment of the principal mines noted by Eschwege was confirmed and somewhat extended by Gorceix and the existence of a second parallel line marked by the smaller workings of Caxambú and Fundão was affirmed.

In recent brief visits to the Ouro Preto region an attempt was made to resolve the doubts suggested by the above studies and to determine the original character and mode of origin of the topaz-bearing material. For this purpose the small mine of Caxambú was selected, as here the topaz bed was tolerably well exposed by recent workings, whereas in the larger mines it is now for the most part concealed and everywhere greatly obscured by landslides. A preliminary examination of these mines fully confirmed the opinion of Gorceix of their substantial identity with that of Caxambú, which may therefore be taken as typical of the topaz mines of the region. On account of the extreme decomposition of most of the material to be examined the problem presented was one of "mud geology"—the attempt to reconstruct from earthy materials the original rock types from which they were derived—and the solution here presented is necessarily largely hypothetical.

The mine is situated on the slope of a low col between the base of the high-rounded campo-covered knob called the Morro de Caxambú, and a lower knob a few score of meters to the southward. In both of these knobs on each side of the col sound rock is exposed in low bluffs. This is a sericitic phyllite heavily charged with fine hematite dust and on the southern side with a considerable amount of rather coarse quartz in scattered grains, which gives the rock the appearance of an iron-bearing quartzite (itabirite), though on examination it is seen to be more micaceous than quartzose. The rock from both of

these bluffs gives a small residue of rolled zircons, most abundant in the more quartzose one, and there can be no doubt that it is a metamorphosed clastic although from its essentially micaceous and ferruginous character, indicating a high percentage in alkalies and iron oxide, it may be suspected that it was not originally a perfectly normal sedimentary clay. On the slope of the col itself and only a few meters away from the mine on the line of strike there is a small exposure of a soft bluish black slate-pencil phyllite, which, in appearance, only differs from the rock of the bluffs on either side in its finer grain, and which is in all respects identical with the one of which an analysis was given in the September number of this Journal from a smaller topaz working in the immediate vicinity. This is a sericite schist free from quartz but heavily charged with iron, and in the paper above cited its low silica and high alkali contents were given as an argument for considering it as, possibly, a sheared eruptive. The absence of rolled zircons in its heavy residue (both the rock at Caxambú and the one analyzed) may be cited as a confirmation, though not an absolutely conclusive one, of this argument.

The mine itself, which is simply a small excavation in earthy material which when soaked with water has much the appearance and consistence of soft soap, exposes a zone some ten or dozen meters wide of bluish and yellowish clays which still distinctly show the nearly vertical lamination of the rocks from which they are derived. The predominant color is bluish but with streaks and patches of yellow which in part represent a more advanced stage of decay of the bluish material, in part, as will be seen farther on, a material of somewhat different structure and composition. The blue clay could be very satisfactorily traced into the slate-pencil phyllite above mentioned and on the other hand into a light yellow micaceous clay, or rather earth, that shows a change of color owing to the more complete hydration of the iron oxide. In the midst of this earthy material that, while still retaining its original form and structure, falls to pieces on the slightest movement, are bands from a few centimeters up to a meter or more in width of a different colored and more plastic earth, carrying oxide of manganese as well as of iron that gives it a darker yellow color passing to brown or black. The contacts between these two kinds of earth are perfectly sharp, like an eruptive contact, and are sometimes accentuated by a concentration of iron and manganese oxides, forming a black sahlband of about a centimeter's width that merges gradually into the general mass of the brownish or yellowish earth. In one case a band was observed having such a black sahlband on one side and on the other a

zone full of angular fragments of the blue phyllite, giving a brecciated appearance.

So far as could be observed, the topazes only occur in this darker-colored earth, and this is in accord with the descriptions given by Eschwege and Gorceix. This earth is evidently the decomposition product of an eruptive rock which though sheared is less perfectly laminated than the blue phyllite in which it is inclosed and which was evidently much more irregular in its composition and structure. This last difference is shown by a considerable variation, in streaks and patches, of the coloration and by the occurrence of nodular masses from the

1

size of a pea up to that of the fist, or larger, of white kaolin, of a dark chocolate-colored earth, or of granular quartz, or of a mixture of these various elements. It is in these nodules that the topaz occurs though in a somewhat irregular manner, since a number of the smaller ones were washed without finding a trace of the mineral.

Of these nodular inclusions the most significant are those of kaolin. The small group exposed on a carefully-scraped face and shown of natural size in fig. 1 is very suggestive of an original porphyritic structure somewhat modified by shearing. The larger and more sheared group shown in fig. 2 exhibits a gneissoid aspect suggestive of the shearing of a granitic or syenitic nodule in a fine-grained rock as, for example in the phonolitic types of the Serras of Tinguá and of Caldas. The larger nodules of white or chocolate-colored earth and of quartz, in some but apparently not all of which the topaz occurs, are too friable to permit of satisfactory sections, but there can be little doubt that they are essentially of the same character. These frequently show a scale-like crust and irregular intercalations from a few millimeters to one or two centi-

meters thick of micaceous material that still retains a lithoid character and is composed almost exclusively of fine flakes of muscovite, which also occurs in considerable abundance and in larger flakes in the earthy and quartzose matter of the nodules.

Washings of the various phases of the topaz-bearing earth give a very abundant slime of earthy iron and manganese oxides and finely divided mica with a greater or less amount that is difficult to estimate of clay matter, leaving a comparatively insignificant residue of mica flakes and fine grains of scaly

2

hematite. The normal earth free from visible kaolin of the specimen of fig. 2 gave 27·8 per cent soluble in hydrochloric acid, of which 3 per cent was manganese oxide, the rest being iron with a very perceptible trace of alumina. The darker earth of the brown clay nodules and that surrounding one of quartz gave about twice as much soluble constituents, that is to say of iron and manganese oxides. The residue after sliming is nearly free from quartz except when quartzose nodules occur. On removing the mica and iron a very slight heavy residue of minute grains and aggregates of rutile and needles of tourmaline remains with very rare and ill-formed grains of green anatase and a comparative abundance of a yellowish phosphatic mineral. The hematite grains are rare in the body of the earth but very abundant when the micaceous crusts above mentioned occur, and the tourmaline is distributed in a similar manner but is nowhere abundant. Rutile appears in all the washings, but is apparently more abundant in the main body

of the earth than in the nodules, while anatase only occurs sporadically. Zircon in extremely minute and usually ill-formed grains of difficult identification was found in the micaceous crusts but only sporadically in washings from other parts. The phosphatic mineral is usually in ill-formed aggregates that sink in the Klein solution, but a few rare crystals of rhombohedral form were detected. By microchemical and blowpipe tests (with the Florence bead) cerium was identified in these grains and this with the rhombohedral form and high specific gravity indicates that the mineral is the cerium-aluminum phosphate, florencite, recently described by Hussak and Prior. Topaz could only be found in some but not all of the nodular masses, but no trace of it could be detected in the main body of the earth free from inclusions. When found it was always in fragments of what had evidently been macroscopic crystals, no perfectly formed microscopic crystals being observed although they were carefully and confidently looked for.

The above observations afford a very insufficient basis for the determination of the original type of the topaz-bearing material, but in view of the interest of the subject and the slight probability of finding better preserved material for study, some hypothetical deductions may be hazarded. In this attempt at reconstructive geology two phases have to be considered, viz. the schistose one from which the earthy matter is directly derived by decomposition, and the original rock type from which this schist was derived by metamorphism accompanied by shearing.

In the schistose phase it is certain that the rock was essentially a micaceous schist, which, as the mica flakes, although minute, are for the most part well formed, can be designated as muscovite rather than as sericite schist. The mica contents of this schist must have varied from about 70 per cent in the normal parts free from segregations to about 30 per cent in the more basic and to almost nothing in the more acid of the latter. The iron and manganese contents varying in the inverse proportion are probably referable to original oxides* and in this case the schist must have been very similar in com-

* Probably but not certainly, as in the immediate vicinity there are extensive deposits of manganese ores that are residues from original carbonates and others that are presumed to be derived from original silicates, while examples of the complete replacement of an iron-bearing silicate (asbestiform amphibole) by limonite are frequent in the neighborhood. In the case in question, however, there are serious difficulties in the way of the hypothesis of the derivation of these hydrous oxides from either a carbonate or a silicate. The other conditions of the bed seem incompatible with the first, and the absence, at least apparent, of secondary silica in the vicinity gives a strong though not absolutely conclusive argument against the second.

position to the blue phyllite with which it is associated, differing principally in the presence of manganese and in the greater susceptibility to hydratization of the hematite grains, since in the residues only an insignificant amount of this mineral appears. This would give a muscovite schist normally free from quartz but heavily charged with metallic oxides and with scattered and more or less crushed crystals of feldspar and nodules of feldspar or quartz, or of mixed feldspar and quartz, with or without specular iron, rutile, topaz and muscovite. These nodules are frequently surrounded by a dark band more heavily charged with the metallic oxides than is the body of the schist and which may be either a primary or a secondary feature, most probably the former since nodules of a similar character and composition also occur. The accessory elements rutile, tourmaline, zircon (?) and florencite are common to both the normal schist and the nodules but are not prominent in either, while topaz, and probably euclase (not identified in any of the samples examined) appear to be confined to the latter. The larger undecomposed minerals of the nodules (quartz, topaz, specular iron, rutile and exceptionally euclase) usually show a certain amount of crushing which is in accord with the sheared condition of the rock as a whole and indicates that the nodular structure is a primary rather than a secondary feature. The circumstance noted by Eschwege and others that only very exceptionally do any of the minerals show double terminations probably indicates that the nodules were originally accompanied by drusy cavities that have doubtless disappeared in the shearing.

In a recent communication in this Journal I endeavored to show from the chemical and mineralogical characters of the schists of this region that many of them are probably sheared eruptives and suggested the hypothesis of decomposition and leaching prior to metamorphism to account for their peculiarities. One of the rocks there discussed is identical with the blue phyllite of the Caxambú mine and is from a topaz washing in the immediate vicinity, so that the arguments there presented are applicable to those here considered. The argument for an eruptive origin is somewhat weakened by the occurrence above noted of very similar, though more quartzose, rocks with clastic zircons on each side of the mine which perhaps may represent a mixture of eruptive and non-eruptive material. Be this as it may, the argument for decomposition and leaching, giving a concentration of iron oxide and alkalies necessary for the formation of a hematite-muscovite schist, still holds good and in this case the associated topaz schist may be presumed to have been similarly affected. An explanation is thus afforded for the peculiar composition of this rock, and with this hypothesis, that of a concentration during the leach-

ing of metallic oxides in certain nodules and about certain others becomes plausible. All things considered, however, it seems more probable that this last is rather due to an original and not a secondary feature.

The question of the original type from which, by shearing and metamorphism, this muscovite-iron-manganese schist was produced, is a more difficult one. Whether the blue phyllite was originally eruptive or not, there can be little doubt that the topaz-bearing schist enclosed in it was so. This is indicated by the character of its contacts, by the absence of clastic elements, by its manganese contents, and by its banded and nodular structure. Being eruptive, it must have been a rock without free quartz but with a comparative abundance of alumina-alkali silicates (feldspars or feldspathoids) and of iron and manganese minerals, which last, if in the state of silicates, must have been bisilicates containing lime and magnesia that have disappeared by leaching either in the recent decomposition, or, as seems more probable, before the metamorphism and shearing. The rock was probably porphyritic in structure (perhaps not necessarily so if an ancient period of decomposition be admitted) and full of segregated masses of both the more acid and the more basic constituents, in the former of which quartz, not a normal constituent of the rock, also appeared. These segregations must have been more or less drusy and in them several minerals, of which some were not normal to the rock, crystallized with one free termination.

The conditions above enumerated point to some member of the augite- or nepheline-syenite groups as the most probable original eruptive type. The rocks of these groups would afford the necessary alumina and alkalies to furnish the abundant mica free from quartz that characterizes the metamorphic schist, while their more or less basic phases would afford the metallic oxides as well, if the accompanying lime and magnesia can be supposed to have disappeared by leaching. Moreover these rocks are particularly subject to rapid alternations in texture or composition, or both, giving segregated masses, or *Schlieren*. In those known to me in various Brazilian localities both acid and basic segregations occur, and frequently one of the former character is surrounded by a zone more basic than the normal rock, thus giving the conditions noted in some of the topaz nests.

In this connection it is interesting to note that the study of the more normal schists of this and of the Diamantina region led to a similar conclusion, that rocks of the augite- or nepheline-syenite groups were probably represented among them, though in this case it seems necessary to admit that clastic as well as eruptive types occur. Combining the two series of observations, the hypothesis may be ventured of the existence in this

region (and various other similar ones in Brazil) of an ancient volcanic series represented by both massive and clastic types, characterized by soda-bearing rocks and ranging from soda-granite through augite- and nepheline-syenite to the extremely basic phases rich in metallic oxides that characterize these groups. In this regard the analyses by Gorceix of various schists from the Boa Vista topaz mine showing comparatively high soda contents are particularly significant. Perhaps also the association, at least apparent, of iron and manganese ores with the schists here discussed, may be taken as an indication in the same direction, but a discussion of the matter must be deferred to another occasion. On this hypothesis the later phases of the eruptives may be supposed to have been characterized by topaz-bearing dikes.

Although topaz has not been recorded as occurring in rocks of the types above mentioned, there is no apparent reason why it should not be found, since the only element required for its formation that is not normally present in them is fluorine, which in the form of fluorite and fluo-silicates is quite frequent in their segregations and drusy cavities. It is worthy of note that its almost constant companions in the granitic rocks in which it has hitherto been found, cassiterite and tourmaline, are only represented by the latter in insignificantly small proportions. Its characteristic companion, if it can be said to have one, is euclase, containing the element glucinum, characteristic of a number of the rare minerals of the nepheline-syenite pegmatites of southern Norway. It may also be noted that in these last mentioned rocks cerium occurs in forms different from the common one of monazite, thus presenting a certain analogy with its occurrence as florencite in the topaz-bearing earth of the Ouro Preto district.*

Whether the above guess as to the original character of the topaz-bearing earth proves correct or not, it is certain that the occurrence of the topaz in the Ouro Preto district does not differ so materially from the other known ones as has hitherto been supposed. That is to say, the mineral does not occur in an essentially magnesian rock nor is its matrix of presumably sedimentary rather than of eruptive origin. On the other hand, the rock cannot be positively identified with any in which the mineral has hitherto been found. Of the known modes of occurrence the only one that offers a more or less remote analogy is that described by Cross in the lithophyses of a rhyolite of Colorado and Utah. As lithophyses are essentially drusy cavities of peculiar character and as rhyolites differ

* This mineral, which was first detected by Hussak in alluvial washings from Tripuhy in the immediate vicinity of the topaz mines, has since been found in a number of diamond residues from the Diamantina district.

from acmite-trachytes and phonolites mainly in the higher proportion of silica, the analogy may be a closer one than at first sight appears.

Both Eschwege and Gorceix noted a linear arrangement of the topaz localities which is also suggestive of occurrence along one or more dikes. The older workings define quite clearly two such lines lying several kilometers apart, but recent prospecting in the soil cap shows that topaz occurs sporadically over much of the intervening belt.

Although the topaz is known to occur in other regions in Brazil, very little definite information can be obtained regarding it. Under the name of *pingos de agua* (water drops) rolled white and blue pebbles were for a long time an article of commerce at the little town of Minas Novas on the Jequitinhonha below Diamantina. This place was a center of trade in various gem stones, other than the diamond (aquamarine, chrysoberyl, tourmaline, spodumene, topaz and andalusite) coming from an extensive region lying between the Jequitinhonha and Doce, but for the most part, if not wholly, outside of the diamond region proper, where it is to be noted the minerals mentioned are extremely infrequent or wholly lacking in the miners residues that have been examined. Some years ago Dr. J. C. da Costa Sena of the Ouro Preto Mining School made a trip in this region and succeeded in finding most of these minerals both in gravel deposits and in the rocks but makes no mention of the topaz, from which it may be inferred that it does not occur in association with the minerals above named. The specimens from this region are often of considerable size, one in the National Museum of Rio de Janeiro being but little short of two kilograms in weight.

Some years ago a gentleman at Serro between Ouro Preto and Diamantina showed me some beautiful little doubly-terminated crystals of white topaz that had apparently been extracted from the original matrix and are presumed to be from somewhere in the vicinity, but I failed to learn the exact locality or conditions of finding. In the diamond region proper the topaz is a great rarity, although Gorceix reports having found it. Eschwege also reports it as occurring in a magnetite-bearing pegmatitic rock on the island of Pescaria near the little town of Sepitiba to the south of Rio de Janeiro. As there is a massif of augite- and nepheline-syenite near by, a detailed examination of this place may perhaps throw some light on the hypothesis above presented, but owing to quarantine restrictions it has not been possible to visit the place in time for the present paper.

São Paulo, Brazil, July 30th, 1900.

Art. III.—*A Chemical Study of the Glaucophane Schists;* by Henry S. Washington.

Introductory.—Among the metamorphic rocks the glaucophane schists are of special interest, on account of their peculiar mineralogical composition, as well as their comparative rarity. It is therefore somewhat remarkable that they have been only slightly investigated from a chemical point of view, especially as the characteristic mineral, glaucophane, has been analyzed from most of the localities. Indeed, as Rosenbusch* has remarked, our knowledge is far from sufficient for a proper understanding of their relations and origin. It is with the object of supplying partially this deficiency that the present chemical investigation has been undertaken. To supplement the analyses, some petrographical description is added, but the geological relationships will be only lightly touched upon, on account of the lack of opportunity for personal observations.

The material from Syra was collected by myself, several years ago, during a day's stay on the island. For the numerous specimens from the other localities I am deeply indebted to petrographers in different parts of the globe, and I gladly take this opportunity to express my hearty thanks to those mentioned in subsequent pages, in connection with the various specimens, for their kindness and generosity, which have made this investigation possible by supplying me with the requisite material.

Syra, Greece.

The glaucophane rocks of this island were first noticed by Virlet,† in 1833, who took the blue hornblende to be in part cyanite. Fiedler‡ in 1841, in a sketch of the geology and archaeology of the island, refers to this mineral as a hornblende, and mentions the abundance of epidote. Glaucophane was indentified as a new mineral in these rocks by Hausmann § in 1845. The rocks of the island were described by Luedecke¶ in 1876, from specimens collected by Fouqué and von

* Rosenbusch, Elemente der Gesteinslehre, 1898, p. 521; also Sitzungsber. Akad. Wiss. Berlin, 1898, p. 706.

† Virlet, Expéd. Scient. de Morée, vol. ii, p. 66, 1833.

‡ Fiedler, Reise durch Griechenland, vol. ii, p. 168, 1841.

§ Hausmann, Gött. gel. Anzeigen., 1845, p. 193, Ref. in Neues Jahrb. 1845, p. 321.

¶ Luedecke, Zeitschr. d. deutsch. geol. Gesellsch., vol. xxviii, p. 248, 1876.

Fritsch, and later the geology, as well as the rocks, were described by von Foullon and Goldschmidt.*

While the glaucophane schists of Syra vary considerably in appearance and composition, yet, according to von Foullon and Goldschmidt, (with whose conclusions my own observations agree, as far as they go), they may be referred to two main types, epidote-glaucophane schist and mica (quartz)-glaucophane schist. These are not divided with absolute sharpness, as some transition forms are found, but, with only one or two exceptions all my specimens may be referred to these two. The more numerous divisions of Luedecke may also be put in one or the other of these two groups, or regarded as transition varieties.

In association with these are found various metamorphic rocks, such as gneiss and epidote schist (which are especially abundant, according to von Foullon and Goldschmidt), omphacite rocks and eclogites, and various augitic and hornblendic schists. All these occur in connection with and interbedded with metamorphosed limestones, but the relations of the different members of the complex are far too intricate and little known as yet to permit of discussion.

Epidote-Glaucophane Schist.—It would seem that the rocks belonging here are rather more abundant than those belonging to the other main group. They vary from coarsely crystalline forms, in which either the glaucophane or the epidote is porphyritic in quite large individuals, to fine-grained varieties, in which the epidote occurs as small patches in the mass of dark blue, silky prismatic glaucophane, forming specimens of great beauty. Garnet is present only to a small extent, and mica, quartz and feldspar are not abundant in the most typical representatives of this type.

The specimen chosen for analysis is from near Kyperusa, a small hamlet about 2½ kilom. north of Hermoupolis, in the northeastern part of the island. It is fine-grained, and shows to the naked eye small prisms of pale greenish yellow epidote with some white flecks of calcite and quartz, lying in a dark blue, silky groundmass of minute glaucophane needles. Under the microscope all these minerals are seen, the glaucophane highly pleochroic, the epidote nearly colorless, together with some chlorite (which is apparently derived in great part from the glaucophane), a few small titanite and rutile crystals, and a little feldspar, which, with the quartz and calcite, is interstitial.

* von Foullon and Goldschmidt, Jahrb. k. k. Geol. Reichsanst., vol. xxxvii, p. 1, 1887.

The analysis (No. I, below) shows a decidedly basic composition, with rather high Al_2O_3 and CaO, considerable Na_2O, and only a trace of K_2O. It will be seen later that it resembles the analyses of several other occurrences of these rocks.

As the mineralogical composition is quite simple, it may be calculated out quite readily as follows. The figures for glaucophane used here are those furnished by an analysis given further on, while those for epidote are based on the analysis by Luedecke.*

Glaucophane	37·2
Epidote	40·2
Chlorite	7·7
Quartz	6·1
Calcite	5·1
Feldspar	2·1
Titanite and rutile	1·6
	100·0

In II there is given an analysis of another specimen from Syra, an omphacite-zoisite rock, composed of bright, grass-green omphacite (diallage) in blades and large crystals, white mica (paragonite), and granular zoisite, with a little interstitial quartz. The content of mica varies considerably, being fairly abundant in the specimen analyzed, and much less so in others.

This resembles I very closely, though Fe_2O_3 is considerably higher than FeO. TiO_2 was not determined, and is included in the Al_2O_3. Even thus the latter is high, but is to be attributed to the abundant zoisite and paragonite. The mineral composition of this calculates out approximately;

Omphacite	31·7
Zoisite	31·7
Paragonite	31·0
Quartz	5·6

Mica-Glaucophane Schist.—The rocks which may be referred to this group are not abundant, but vary considerably in character, and, through decrease in the amount of mica tend to become quartz-glaucophane schists. The specimen which was chosen for analysis seemed to be fairly typical. It came from near the Café Skarbeli, on the east coast, a short distance to the north of Hermonpolis on the east coast.

It is markedly schistose, and shows megascopically glaucophane, white mica, greenish epidote and diallage, and small

* Luedecke, op. cit., p. 262.

red garnets, the whole being rather fine-grained and traversed by veins of quartz, which were carefully avoided in the pieces chosen for analysis.

Under the microscope the glaucophane appears in long crystals, with fringed ends, of the normal gray-blue color and pleochroism, the blue being deeper at the borders. The epidote is slightly greenish yellow, in elongated crystals, and much broken. It is sometimes difficult to distinguish it from the diallage, which occurs in generally larger crystals and less green in color. The garnets are almost colorless and much cracked. The flakes of mica present the usual characters of muscovite, but they must be referred to the soda-mica paragonite, on account of the mere trace of K_2O which the analysis reveals. Apart from the veins, grains of quartz are fairly abundant, scattered through the other constituents and interstitial. Small brown titanites are seen here and there, a little chlorite is present, and also grains of an apparently alkaline feldspar.

Through the kindness of Prof. Lawson and Dr. Ransome, I have been enabled to study specimens and sections of the lawsonite-bearing schists of California, but have been unable to find any of this interesting mineral in the rocks of Syra.

The analysis (No. III, below) shows a much higher percentage of SiO_2 than the preceding, slightly lower Al_2O_3 and Fe_2O_3, the same MgO and FeO and K_2O, with lower CaO and higher Na_2O. In nearly all respects, with the notable exception of the Na_2O, it is transitional between the analyses of the more basic rock and that of the quartz-glaucophane schist to be given presently, and this intermediate character is quite consonant with its complex and transitional mineral composition. In its general features it resembles the analyses of many diorites, and it may be mentioned here that this analysis is quite unique among the dozen or so given in this paper.

The mineral composition being so complex, any satisfactory calculation of the relative amounts of the component minerals is difficult, and would be arbitrary.

Quartz-glaucophane Schist.—It has already been said that von Foullon and Goldschmidt divided the glaucophane schists of Syra into the two groups in which the blue hornblende was associated with either epidote or mica. While this is in general true, and in correspondence with the megascopical appearance of the rocks, yet it does not recognize fully enough the fact that the mica-glaucophane schists tend to become highly acid through the increase in quartz and decrease in mica. I have therefore referred some of my specimens to a third group of quartz-glaucophane schists, in which the mica, while present, and prominent in the hand specimen, yet is in

subordinate amount, and quartz very abundant. This division seems also to be in accordance with facts observed elsewhere.

Some of these schists resemble closely the preceding, and are rather bluish-gray, fine-grained, and highly schistose. The specimen taken for analysis differs from all these, and is a very striking rock, resembling (as far as can be told from the description) some of the quartz glaucophane schists of Angel Island, described by Ransome, to be mentioned later.

It is a highly schistose, shining white rock, from the northwest slope of Mt. Kappari. It is composed largely of quartz and less white mica, forming a fine-grained groundmass, through which are scattered blades of blue glaucophane, and some garnets about one cm. in diameter. Accessory epidote and apatite are also present in small amount.

The analysis (No. IV, below), it will be seen, differs radically from those of the other Syra rocks, being very acid, and with all other oxides much lower, except K_2O, which is quite high. In a general way it resembles those of the acid glaucophane schists of the Pacific coast.

	I.	II.	III.	IV.
SiO_2	46·39	46·76	58·26	79·43
Al_2O_3	17·34	22·65	16·21	12·68
Fe_2O_3	6·32	4·35	3·44	1·10
FeO	4·62	1·74	4·63	1·86
MgO	4·93	3·93	4·99	0·48
CaO	13·07	14·43	3·82	1·40
NaO	2·95	2·36	5·36	1·61
K_2O	0·25	0·15	0·39	0·76
H_2O 110° +	1·48	2·87	0·98	1·03
H_2O 110° —	0·08	0·16	0·22	0·12
CO_2	2·24	----	----	0·00
TiO_2	0·85	not. det.	1·37	0·17
MnO	trace	trace	trace	trace
	100·52	99·40	99·67	100·64

I. Epidote-glaucophane schist. Kyperusa, Syra. Washington anal.

II. Omphacite rock. Café Skarbeli, Hermoupolis, Syra. Washington anal.

III. Mica-glaucophane schist. Café Skarbeli, Hermoupolis, Syra. Washington anal.

IV. Quartz-glaucophane schist. N.W. slope of Mt. Kappari, Syra. Washington anal.

In connection with the glaucophane schists of Syra, it will be convenient to give the results of an analysis which I made of the glaucophane of the island. The mineral was very carefully separated by means of Thoulet's solution from a

rather coarse-grained specimen of quartz-mica-glaucophane schist, with a few accessory garnets. It just sank in a solution of sp. gr. 3·11, and was examined with the microscope and seen to be extremely pure.

My analysis (the mean of two) is shown in I, and for comparison are given the analyses of Luedecke (II) and Schnedermann (III), taken from the paper of Luedecke (p. 252), already cited. It is hoped to discuss this analysis, along with other new ones, in a subsequent paper.

	I.	II.	III.
SiO_2	57·67	55·64	56·49
Al_2O_3	11·07	15·11	12·23
Fe_2O_3	3·20	3·08	----
FeO	9·68	6·85	10·91
MnO	0·06	0·56	0·50
MgO	9·85	7·80	7·97
CaO	0·95	2·40	2·25
Na_2O	6·80	9·34	9·28
K_2O	0 42	----	----
H_2O 110° +	0·36	----	----
H_2O 110° —	0·12	----	----
	100·18	100·78	99·63

Attica.

The investigation of Lepsius* have shown that both the gabbros and the Cretaceous shales of Attica have been altered to glaucophane schists, through regional metamorphism.

	I.	II.
SiO_2	48·00	45·97
Al_2O_3	15·80	18·18
Fe_2O_3	11·76	5·95
FeO	3·29	2·30
MgO	7·70	7·50
CaO	5·51	8·29
Na_2O	3·42	4·10
K_2O	0·46	0·75
H_2O	4·20	6·50
P_2O_5	trace	trace
S	trace	----
MnO	trace	trace
	100·14	99·54

I. Gabbro. Kypriano, near Laurium. Lepsius anal., op. cit., p. 101.

II. Gabbro. Malje Kuki, near Daskalio. Lepsius anal., op. cit., p. 102.

*Lepsius, Geologie von Attika, Berlin, 1893.

Unfortunately he gives no analyses of true glaucophane schists, but it seems worth while quoting the above two analyses of gabbros, which have partially undergone the transformation. Both are composed chiefly of plagioclase and diallage, which has been largely altered to fibrous green hornblende, with considerable glaucophane in needles. Chlorite and magnetite occur, but no olivine nor serpentine was seen.

Lepsius* also describes a blue gray, partially schistose rock, from west of Olimpos in Attica, composed of glaucophane needles lying in a groundmass of quartz and feldspar. A silica determination gave 87·43 per cent, and it is evident that this is a quartz-glaucophane schist, analogous to those of Syra, and, as will be seen later, of the Pacific Coast and elsewhere.

Croatia.

In 1887 Dr. Kišpatić† described a number of glaucophane schists, which occur chiefly as boulders or pebbles in various streams of Fruska Gora in Croatia. They vary to some extent, but it is of great interest to note that they may all be classed as either epidote-glaucophane schists, to which the majority belong, or as quartz-glaucophane schists, which are represented by only two occurrences. Garnet is sometimes present in abundance, sometimes quite wanting, and mica is rare, even in the more acid group.

I am indebted to Prof. Rosenbusch for one of Kišpatić's specimens from the Srnjevacki Potok. It is of very simple composition, being composed chiefly of frayed, pleochroic glaucophane, and colorless or pale yellow epidote, in grains and prismatic crystals. Between these, but in very small amount is a colorless mineral, which occasionally shows multiple twinning lamellæ, and is referred to plagioclase. There are also rare rutile grains.

In thin section my specimen corresponds very well with Kišpatić's description. The rock is very fine-grained, composed of a pale glaucophane, in xenomorphic masses, with abundant grains and stout crystals of colorless or pale yellow epidote. A colorless mineral, apparently a plagioclase, as suggested by Kišpatić, is rare, in interstitial grains.

The analysis shows low SiO_2, and resembles in a general way that of the Kyperusa rock. It differs, however, in having much higher MgO and lower CaO, as well as in the absence of CO_2.

* Lepsius, op. cit., p. 104.

† Kišpatić, Jahrb. k. k. geol. Reichsanst., xxxvii, p. 35, 1887.

SiO_2	47·36
Al_2O_3	19·74
Fe_2O_3	3·10
FeO	5·71
MgO	8·24
CaO	4·63
Na_2O	3·57
K_2O	0·51
H_2O 110° +	5·89
H_2O 110° −	0·16
CO_2	trace
TiO_2	1·36
MnO	trace
	100·27

Epidote-glaucophane schist. Srnjevacki Potok, Fruska Gora, Croatia. Washington anal.

Anglesey, Wales.

The occurrence of glaucophane schists on Anglesey was first observed by Blake* in 1888. The area is small and the composition apparently quite uniform, only epidote-glaucophane schist being mentioned. This occurs as local modifications of a hornblende schist which is probably derived from a diorite, which occurs in the vicinity.†

Through the kindness of Mr. Teall and Mr. E. B. Greenly I received specimens from the most typical locality, "The Monument," near Menai Bridge, on Anglesey, one of which was analyzed.

The specimens are very uniform, and are dense, compact, fibrous rather than foliated, schists, of a dark, blue-black color,

SiO_2	47·47
Al_2O_3	15·25
Fe_2O_3	8·22
FeO	7·19
MgO	5·96
CaO	11·32
Na_2O	2·11
K_2O	0·56
H_2O 110° +	2·13
H_2O 110° −	0·04
TiO_2	not det.
MnO	trace
	100·25

Epidote-glaucophane schist. The Monument, Anglesey, Wales. Washington, anal.

* Blake, Geol. Mag., Decade III, vol. v, p. 125, 1888.

† Blake, Rep. Brit. Assoc. Adv. Sci., 1888, p. 406. Also op. cit., p. 125. Harker, Petrol. for Stud. 1897, p. 314.

and somewhat silky luster. Under the microscope they correspond with the plate given by Teall*, and are seen to be composed of a rather pale, prismatic glaucophane, with the normal pleochroism, rather less pale epidote, and small amounts of magnetite, quartz, mica and titanite. No calcite was seen.

Piedmont.

The occurrence of glaucophane schists in Piedmont is well known, and has been described by many geologists, but as I had no specimens from this region, I have passed it by in the preceding pages. Since they have been put in type, however, I have discovered an analysis of one of the rocks of this region, which is inserted here.

The occurrence of glaucophane schists and amphibolites ("prasinites") in the Val Maira, in southwestern Piedmont, is described by S. Franchi,† who also shows that they are both derived from diabases by metamorphism, apparently regional. The glaucophane schists are described as composed of glaucophane (gastaldite), with epidote and chlorite, and less albite, quartz, titanite and calcite. Analyses of this and of the amphibolite are given, and the very close correspondence between the two is evident. This is a strong point in favor of the view elsewhere expressed, that the formation of these two rocks is due, not to age distinctions, but to differences in conditions during metamorphism.

	I.	II.
SiO_2	48·67	50·38
Al_2O_3	18·36	17·65
Fe_2O_3	10·30	10·02
FeO	----	----
MgO	5·49	4·77
CaO	11·03	10·95
Na_2O	1·12	2·52
K_2O	0·11	0·24
H_2O	4·20	2·52
TiO_2	0·45	1·32
P_2O_5	trace	trace
	99·75	100·37

I. Glaucophane schist, Val Maira, Piedmont. Aichino anal. S. Franchi, Boll. Com. Geol. Ital., xxvi, p. 199, 1895.

II. Amphibolite ("Prasinite"), Valle del Sangone, Piedmont. Aichino anal. S. Franchi, op. cit., p. 199.

Corsica.

For the sake of completeness there may be mentioned two glaucophane rocks of Corsica, which have been analyzed.

* Teall, Brit. Petrog. 1888, pl. xlvii, fig. 1.

† S. Franchi, Boll. Com. Geol. Ital., vol. xxvi, p. 192, 1895.

One is a gray-green schist from the neighborhood of a large serpentine dike, at La Barchetta, near Bastia, of which, not having access to the original paper by Oels,* I can give no description. It is, however, possibly the same as that described by Oebekke† from the same locality, as composed of prismatic glaucophane, partly altered to chlorite, granular epidote, plagioclase, quartz and calcite.

The analysis (No. I, below) shows low SiO_2 and CaO, with very high alkalies, and Fe_2O_3 largely preponderating over FeO. It does not correspond with the description given by Oebekke, nor, in fact, as far as the iron oxides and alkalies are concerned, with any other analysis of a glaucophane schist.

The other is a glaucophane schist from the gneiss of Bastia,‡ a dark, fine-grained, tough rock, composed of "orthoclase, some oligoclase, needles and prisms of glaucophane, sahlite, iron mica and chlorite, with other secondary products."

The analysis, given in II below, is unsatisfactory, and of little value, as FeO, alkalies and H_2O have not been determined. As far as it goes it is rather anomalous for a glaucophane schist, and resembles most that of the rock from Café Skarbeli, in Syra.

	I.	II.
SiO_2	50·17	55·94
Al_2O_3	13·88	18·06
Fe_2O_3	7·80	12·17
FeO	1·69	
MgO	4·53	2·75
CaO	10·90	5·95
Na_2O	7·31	5·13 (difference)
K_2O	2·16	
H_2O	1·56	not. det.
Mn_3O_4	0·59	----
	100·59	100·00

I. Glaucophane schist. La Barchetta. Bastia. Corsica. M. Oels anal. Ref. in Neu. Jahrb. 1896, i, p. 47.

II. Glaucophane schist, near Bastia, Corsica. Busatti anal. Ref. in Neu. Jahrb., 1897, i, p. 281.

Japan.

Glaucophane schists are of quite common occurrence among the metamorphic rocks of Japan,§ and a number of them have been described by Kotô. From him I received several specimens of typical material, two of which were analyzed.

* M. Oels, Inaug. Diss. Erlangen. 1894, Ref. in Neues Jahrb. 1896, I, p. 47.

† Oebekke, Zeitschr. d. deutsch. geol. Ges., vol. xxxviii. p. 647, 1886.

‡ Busatti, Atti Soc. Tosc. Sci. Nat., Mem. xiii, p. 1–19, 1894: Ref. in Neues Jahrb. 1897, i, p. 281.

§ Kotô, Jour. of Sci. College, vol. i, Pt. i, p. 85, 1886. Harada, Die Japanischen Inseln, Berlin, 1890, pp. 54, 62.

Epidote-Glaucophane Schist.—One of these specimens is a rock of this character from Hongô, in Norimoto Village, Yana District, Province Mikawa. It is compact, of a rather dark, greenish gray color, and schistose with a silky luster. The specimen is traversed by a vein of calcite, which was avoided in the material chosen for analysis. The microscope, as well as the analysis, shows that this mineral is present throughout the rock to a considerable extent.

The structure of the rock as seen by the microscope differs from most of the other specimens examined, in the very finely fibrous character of the glaucophane, which is rather pale, but of the usual pleochroism. This forms streaks and bands through the rock, bringing out the schistose structure, and also occurs as a sort of felt. With it, but somewhat locally developed, is a pale green or bluish-green, not highly pleochroic, amphibole, also in needles, which seem to be an actinolite and to be derived from the glaucophane. A yellowish epidote occurs in small grains, chiefly intimately associated with the glaucophane.

Partly intermingled with these three, but generally forming the greater part of separate streaks, is a colorless mineral of rather high refraction and low birefringence, the polarization colors being grays and blue-grays. It is chiefly in long grains, not showing much cleavage, and is apparently orthorhombic. This must be referred to zoisite, as the low alkalies preclude the possibility of its being a feldspar. Calcite is quite common, and some grains of quartz are seen. Titanite is also present in small grains.

The analysis of this rock, given in I below, is that of a normal epidote-glaucophane schist, with high CaO. It calls for no special remark here.

A specimen of glaucophane schist from Otaki-san, near Tokushima, Shikoku Island, represents the rocks in which glaucophane was first discovered in Japan by Kotô, and which have been briefly described by him. The majority of them would seem to be epidote-glaucophane schist, some containing garnets, but the one in my possession is a quartz-glaucophane schist. Unfortunately it is seemingly so badly altered that no analysis was made of it, but a brief description may be of interest.

It is a highly fissile, schistose rock, of a general brownish color, glistening with mica scales, and with abundant dark blue glaucophane. Microscopically it is composed of stout prisms of dark glaucophane, white mica, and considerable interstitial quartz. Small crystals of colorless titanite, apatite and zircon (?) are numerous. Brown limonitic stains over all

the section indicate the decomposition of the specimen, but it is more fresh than the megascopic appearance would indicate.

"*Glaucophane Slate.*"—The second specimen which was chosen for analysis is one of a rock called by this name by the Japanese geologists. According to Kotô* they are extensively developed in the Paleozoic of Japan, and are really "schalsteins," derived from diabase tuffs. The specimen in question, from Kamoi Kotan, Island of Hokkaido (Yesso), is a very fissile, slaty, fine-grained rock, of a general light, blue-gray color, but stained between the folia with limonite.

Under the microscope it is seen to be very fine-grained, and with the detrital, cataclastic structure of the original diabase tuff very well marked. There are irregular patches of a pale, fibrous glaucophane, with some rather large crystals and fragments of pyroxene, but the greater part is an indeterminate, very finely granular mass of colorless and yellow grains and fragments, mostly of augite, with some of glass, and possibly of plagioclase.

The analysis (No. II) resembles the preceding in many respects, but is lower in CaO, and higher in iron oxides, K_2O and TiO_2. H_2O is high, but no CO_2 was found.

The analysis, on the whole, confirms the view that the rock is a metamorphosed diabase tuff, and for comparison, analyses of two of these are given in III and IV.

	I.	II.	III.	IV.
SiO_2	47·89	48·88	47·25	49·13
Al_2O_3	13·06	13·44	17·84	14·76
Fe_2O_3	6·77	5·32	5·46	16·40
FeO	5·36	8·96	7·20	----
MgO	4·10	4·21	5·97	4·41
CaO	11·65	5·80	5·15	9·05
Na_2O	3·35	3·73	2·30	2·96
K_2O	0·57	1·71	0·29	1·81
H_2O 110°+	1·39	3·42	8·55	
H_2O 110°—	0·12	0·36		1·66
CO_2	2·97	none	----	
TiO_2	2·14	3·90	in Al_2O_3	----
MnO	0·09	----	0·14	----
	99·46	99·73	100·15	100·18

I. Epidote-glaucophane schist. Norimoto, Yana Distr. Mikawa Prov. Japan.

II. "Glaucophane slate." Kamoi Kotan. Isl'd Hokkaido. Japan.

III. "Schalstein." Nogurizawa. Kanra Distr. Kozuke Prov. Japan. Harada anal. Harada. Die Jap. Inseln., p. 66.

IV. "Schalstein." Siebenhitz. NW of Hof. Bavaria. Schwager anal. Gümbel, Geogn. Beschr. Fichtelgeb. 1879, p. 227.

* Kotô, op. cit., p. 89.

California.

Coming to our own continent, we find glaucophane schists only in the extreme west, where they are extensively developed along the Pacific Coast, in California and Oregon, and possibly beyond these. They are very varied in character, and have been described in part by many geologists, but their relationships and origin are not yet fully understood. Some of them would seem to be the products of regional metamorphism, while in other cases they are due to contact metamorphism and are local in character.

They also vary widely in composition, but the researches already made by others, as well as the analyses given here, show that, just as in Syra, Croatia and Brittany, they belong to two groups, the basic and the acid. As the occurrences are somewhat widespread, they will be described under local headings.

Santa Catalina Island.—The geology of this island, which lies off the coast of Southern California, has been described by W. S. T. Smith.* It is composed largely of diorites and andesites, resting on a basement of quartzite and schists, in which also serpentine occurs.

Of the occurrence of the glaucophane schists he speaks as follows: "Besides the micaceous partings of the quartzites there were found at a number of points partings of blue amphibole, having frequently a silky luster. This amphibole also occurs in larger masses in a schistose condition. The occurrences of this rock are found particularly in the Little Harbor region, apparently confined to the neighborhood of areas of the amphibole, and talc-schists and serpentine. It is probable that here, as elsewhere in California, these blue amphibole schists are due to local contact metamorphism occasioned by the intrusion of basic eruptives."

Dr. Smith does not describe these rocks further, but in the petrographic collection of Yale University is a suite of rocks from Santa Catalina Island, collected by Prof. B. Silliman in 1867, among which are several specimens of the glaucophane schists from Little Harbor, on the west coast. I am indebted to Prof. Pirsson for the privilege of studying these, as well as material for analysis.

They all prove to be quartz-glaucophane schists, pale, blue-gray in color, rather ashy and dull, one fibrous, and the others (including the specimen analyzed), very schistose and fissile, though quite hard. One specimen shows thin bands of white quartz.

* W. S. T. Smith, Proc. Cal. Acad. Sci., (3), Geol., vol. i, p. 1, 1897.

Under the microscope the specimen analyzed shows a multitude of fine, pale blue glaucophane needles, and larger crystals fringing out into needles, embedded in granular quartz, with some minute zircons and a few grains of epidote. There is no carbonaceous matter present, but in another similar specimen this exists to a considerable extent, while a dark, compact rock, also from Little Harbor, is a black and apparently little altered, quartzose shale.

	I.	II.	III.
SiO_2	74·48	80·21	74·16
Al_2O_3	9·15	7·99	11·85
Fe_2O_3	1·41		0·82
FeO	4·12	3·35	1·66
MgO	3·04	1·54	2·10
CaO	2·84	1·10	2·10
Na_2O	2·24	5·97	6·57
K_2O	0·43	0·22	0·15
H_2O 110°+	2·06	0·74	0·52
H_2O 110°—	0·08		0·05
CO_2	----	----	0·09
TiO_2	----	----	0·37
P_2O_5	----	----	0·08
MnO	----	----	0·06
C	----	----	0·18
	99·85	101·12	100·76

I. Quartz-glaucophane schist. Little Harbor, Santa Catalina Island, Cal. Washington anal.

II. Quartz-glaucophane schist. Angel Island, Cal. Ransome anal. Bull. Dept. Geol. Univ. Cal., vol. i, p. 231.

III. Adinole, Mansfield, Mich. Steiger anal. Clements. This Journal, vol. vii, p. 88, 1899.

The analysis shows that quartz is very abundant, more so indeed than the microscopical examination would have led one to suppose. It is possible, to judge from the amount of Al_2O_3, that sillimanite is present, since Smith speaks of it as occurring in the neighboring quartzite. None was seen in the sections, though the dense felt of glaucophane needles would make its identification difficult.

It may be inferred from the presence of carbonaceous matter in some of the specimens, and from the apparent gradation to true shale shown by them, that these schists are derived from shales of a quartzose character, or from the quartzites as Smith suggests, possibly through the contact metamorphism of intruded igneous rocks.

It may be mentioned that the analysis corresponds very well with that of an adinole (III above), derived from a clay slate

by contact metamorphism of a dolerite, at Mansfield, Michigan, described by Clements.* The adinole carries abundant albite, and actinolite instead of glaucophane. This difference may be connected with the higher Al_2O_3 and Na_2O and lower FeO in the adinole.

Angel Island, Cal.—The occurrence just described seems to be analogous with that at Angel Island, in San Francisco Bay, described by Ransome,† the similarity being also remarked on by Smith (p. 57). At the latter locality radiolarian cherts have been altered into quartz-glaucophane schists by the intrusion of fourchite and serpentine. They vary rather more in character, as some are composed essentially of glaucophane and albite,‡ while others are made up of glaucophane and quartz. Brown mica and garnet also occur. Analysis II above, by Ransome, shows the essentially general similar character of the two, though it was made evidently of an albitic schist.

It is of interest to note that, just as carbonaceous matter is preserved in the Santa Catalina schists, so in these from Angel Island the radiolarian remains are not entirely obliterated by the metamorphism.

Mount Diablo.—Among the metamorphic rocks of this locality glaucophane schists occur,§ but unfortunately detailed petrographic descriptions seem to be wanting. One of them, a bowlder from Pine Canyon, has been analyzed by Melville.‖ It is briefly described as bluish with streaks of green, with well marked schistose structure, and containing innumerable cinnamon garnets. It is composed presumably chiefly of glaucophane, epidote and garnet, with few accessories, and is probably closely similar to some of the glaucophane schist of Tupper Rock, Oregon, or a specimen from Tiburon Peninsula, sent me by Prof. Lawson. The analysis is given on the next page.

In a recent paper¶ Turner throws some doubt on the interpretation of these schists as the product of contact metamorphism by basic intrusions, but discussion of this problem is outside the scope of this article.

Sulphur Bank.—Glaucophane schists from this locality, which lies east of Clear Lake (north of the preceding locality), have been described by Becker.** They vary much, as elsewhere, some being quartz-mica-glaucophane schists, and others

* Clements, this Journal, IV, vol. vii, p. 88, 1899.

† Ransome, Bull. Dept. Geol. Univ. Cal., vol. i. p. 211, 1894.

‡ Turner (17th Ann. Rep. U. S. G. S., i, p. 728, 1896) suggests that they may be in reality dike rocks.

§ Turner. Bull. Geol. Soc. Amer., vol. ii, p. 384, 1891.

‖ Melville, Bull. Geol. Soc. Amer., vol. ii, p. 413, 1891.

¶ Turner, Jour. Geol., vol. vi, p. 490, 1898.

** G. F. Becker, Mon. XIII, U. S. G. S., p. 102, 1888.

SiO_2	47·84
Al_2O_3	16·88
Fe_2O_3	4·99
FeO	5·56
MgO	7·89
CaO	11·15
Na_2O	3·20
K_2O	0·46
H_2O 105°+	1·81
H_2O 105°—	0·17
P_2O_5	0·14
MnO	0·56
	100·65

Garnet-glaucophane Schist. Pine Canyon, Mount Diablo. Melville anal. Bull. Geol. Soc. Amer., vol. ii, p. 413, 1891.

zoisite-glaucophane schists. One of the last was analyzed, and is described by Becker as follows.

"It is a greenish-gray, schistose rock, consisting chiefly of glaucophane and zoisite. The latter occurs in imperfect prismatic crystals. The zoisite is distinctly dichroic and has a faint olive-green tint when the prisms are parallel to the principal section of the nicols. Sections perpendicular to the main axis are square, often with one truncated corner. The extinctions are normal and the colors of interference are gray to yellow in the prisms, but more vivid in granular aggregates. The angle of the optical axes appears to be large. Glaucophane, in needles and long, imperfect, nearly parallel prisms, gives the rock its cleavage. Quartz, albite, muscovite and titanite are present."

The occurrence of a purely zoisite-glaucophane schist, as described by Becker, is decidedly unusual, and the determination of all the supposed zoisite as such would seem to be somewhat problematical. It is true that some of the mineral was separated and analyzed,* the results corresponding fairly well with the determination as zoisite, but being not inconsistent with an epidote low in iron. The color and pleochroism are also unusual for zoisite. It would seem probable that both minerals exist in the rock, the granular form being probably especially referable to epidote.

Melville's analysis (I) shows a composition closely resembling the preceding one, and like other glaucophane schist analyses, with high CaO. It is of interest to compare with it an analysis of a diabase (Becker's pseudodiabase) from Mt. St. Helena, also by Melville. It will be seen that the two are almost identical.

* Becker, op. cit., p. 79.

	I.	II.
SiO_2	49·68	49·08
Al_2O_3	13·60	14·68
Fe_2O_3	1·86	1·95
FeO	8·61	9·63
MgO	6·27	6·69
CaO	10·97	10·09
Na_2O	3·09	4·60
K_2O	0·12	0·20
H_2O 100°+	3·84	1·18
H_2O 100°−		0·28
TiO_2	1·31	1·72
P_2O_5	0·21	0·23
MnO	0·04	0·15
	99·60	100·48

I. Zoisite-glaucophane schist. Sulphur Bank. Melville anal. Becker, Mon. XIII U. S. G. S., p. 104, 1888.

II. "Pseudodiabase." Mt. St. Helena. Melville anal. Becker, op. cit., p. 98.

While we are still in California, there may be quoted, for the sake of completeness, two analyses given by Rosenbusch. The first (I) is of a specimen sent him by Palache, of a "Grunschiefer with glaucophane, further stage of altered tuff. Hills north of Berkeley." This is calculated from two partial analyses and an alkali determination.* It shows a composition very low in SiO_2 and MgO, probably high in iron, and high in CaO and Na_2O, differing materially from others only in the lower SiO_2.

The second† (II) is of the albite-crossite rock described by Palache,‡ and which Turner§ thinks may be a dike rock.

	I.	II.
SiO_2	42·59	65·2
Al_2O_3	31·00	15·8
Fe_2O_3		2·7
FeO		2·4
MgO	5·10	2·4
CaO	10·80	0·6
Na_2O	4·16	10·8
K_2O	1·01	0·1
H_2O, CO_2	5·34	....
	100·00	100·0

* Rosenbusch, Sitzungsber. Preuss. Akad., 1898, p. 716.

† Rosenbusch, op. cit., p. 712.

‡ Palache, Bull. Dept. Geol. Univ. Cal., vol. i, p. 181, 1894.

§ Turner, 17th Ann. Rep. U. S. G. S., i, p. 728, 1896.

Rosenbusch calculated the rock composition from the specific gravities of the rock and of the two minerals, and their known chemical composition. He gives two limiting results, but, as they differ but little, that corresponding to the mineral mixture $Ab_{75}Cr_{25}$ is here given. As Rosenbusch remarks, this composition is quite anomalous, whether for eruptive or metamorphic rocks, and it is to be desired that an analysis of the rock itself were available.

Oregon.

Glaucophane schists, both acid and basic, occur along the coast in Oregon, and have been partially described by Diller,* who suggests that, as at Angel Island, they are the products of contact metamorphism. He very kindly sent me a number of typical specimens, three of which I have analyzed.

That from a ledge about one mile N.E. of Winston's bridge, near Roseburg, is a schistose, gray (scarcely blue) fine-grained rock, with many glistening flakes of white mica sprinkled through it. One specimen shows some small brown garnets. The other (analyzed) is wanting in them, and is composed of a felt of stout, rather short glaucophane crystals, with grains of epidote, some chlorite, a few irregular quartz grains, and phenocrysts of colorless mica.

Chemically (I) it is the most basic of all these rocks which have been analyzed with the exception of the one partially analyzed by Rosenbusch. It is also very high in iron, low in CaO, and, for these rocks, high in K_2O, which indicates that the mica is a muscovite and not a paragonite, as in the Syra rocks.

Glaucophane schists also occur southwest of Roseburg, in the neighborhood of Coos Bay. Those from Tupper Rock have been briefly described by Diller, and three specimens sent me indicate that they vary considerably in character. Two are composed essentially of glaucophane embedded in granular quartz, with some white mica, and a little epidote. The chemical composition of these must be closely similar to that from Four Mile Creek, described later. The other (III) is much more basic, composed of glaucophane with less granular epidote, or zoisite, in which lie many small garnets, around which are zones of white mica. This corresponds more nearly in chemical composition to the Mount Diablo occurrence.

The schist from Four Mile Creek, Coos County, is a rather coarser grained, schistose rock, of a general light gray color, showing considerable white mica and quartz. In general

* Diller, 17th Ann. Rep. U. S. G. S., i, p. 454, 1896; Geol. Atlas of U. S. Roseburg Folio, 1898.

appearance it is not unlike the intermediate mica-glaucophane schist from Cafe Skarbeli, Syra, already described. In thin section it is seen to be composed very largely of quartz, which shows clear evidence of crushing. In this lie well-formed glaucophane prisms, which are highly pleochroic, c blue, b violet, a pale yellow or colorless. With these, but in less amount, are thin flakes of colorless mica, which the analysis shows to be muscovite scales and plates of chlorite, and some small garnets.

The analysis (II) shows an exceedingly acid composition, being the highest in SiO_2 of any of the rocks so far examined by me. On calculation the mineral composition works out as follows:

Quartz	67·6
Glaucophane	14·2
Muscovite	10·4
Garnet, Chlorite	7·8
	100·0

The relatively high K_2O in both these Oregon rocks is noteworthy, the nearest approach to them in this respect being the "glaucophane slate" of Kamoi Kotan in Japan.

	I.	II.	III.
SiO_2	46·07	82·53	49·15
Al_2O_3	15·35	6·88	15·87
Fe_2O_3	3·61	0·59	4·10
FeO	9·87	4·11	7·58
MgO	7·83	1·86	7·53
CaO	4·37	0·68	9·06
Na_2O	3·22	1·21	3·59
K_2O	2·68	1·24	0·54
H_2O 110°+	4·25	1·35	1·07
H_2O 110°−	0·16	0·07	0·16
CO_2	1·05	----	none
TiO_2	1·63	----	1·19
MnO	trace	trace	trace
	100·09	100·52	99·84

I. Epidote-glaucophane schist. Near Winston's Bridge, Roseburg, Douglas Co., Oregon. Washington anal.

II. Quartz-glaucophane schist. Four Mile Creek, Coos Co., Oregon. Washington anal.

III. Garnet-glaucophane schist. Tupper Rock, near Brandon, Coos Co., Oregon. Washington anal.

General Conclusions.

It will be of interest to compare the foregoing analyses with each other, and for this purpose those which seem to be of most value are collected in the large table on page 55. It is at once evident that these rocks are divided into at least two main groups. One, the larger, is basic, with SiO_2 ranging only from 46 to 49·7, the other is very acid, with SiO_2 ranging from 74·5 to 82·5. These two seem to be very sharply separated, a possible third intermediate group being represented by only one analysis, with SiO_2 58·3.

Basic Group.—Taking up the basic group first, it is seen that they are of fairly uniform composition in most respects. Al_2O_3 in most of them is rather low, from 13 to 15, being higher only in II (17·34), III (19·74) and V (16·88) and VII (18·36). Iron oxides are high in all, and FeO uniformly surpasses Fe_2O_3 (molecularly), in two cases (I and X) very much so. MgO varies from 4·1 to 8·2, and there seems to be no correlation between it and any other oxide, though there are indications of a parallel variation of it and FeO.

CaO shows the most striking behavior, running from 4·4 to 5·8 in some, and then with a break from 11 to 13 in others. It would be natural to connect this behavior with some corresponding difference in mineral composition, but I have failed to find any trace of such. One would suppose that the rocks rich in CaO might be prone to carry garnets, but, while they are abundant in V and IX they are lacking in II, IV, VI and X. On the other hand they are quite wanting in I, III and VIII, in which CaO is low.

Na_2O remains very steady, varying only from 1·1 to 3·7, while K_2O is present, as a rule, only in traces, being above one per cent only in I (2·7) and VIII (1·7). H_2O is, of course, present in considerable, but varying, amount, and CO_2 likewise is irregular, being often quite absent, and again high. TiO_2, when determined, is always high, a fact connected with the frequent occurrence of rutile and titanite as accessory minerals. P_2O_5 and MnO are present only in traces.

Acid Group.—Inasmuch as in this group SiO_2 constitutes 75 to 80 per cent of the rock, the distribution of the other oxides through the remaining 25 to 20 per cent allows of a comparatively small range in variation. It may be noted, however, that FeO is constantly higher than Fe_2O_3, that MgO is rather high for such acid rocks, that CaO decreases regularly as SiO_2 increases, and that Na_2O is constantly higher than K_2O, which, except in XV, is present only in traces. The very high Na_2O in XIV is undoubtedly to be attributed to the presence of albite.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.
SiO_2	46·07	46·39	47·36	47·47	47·84	47·89	48·67	48·88	49·15	49·68	58·26	74·48	79·43	80·21	82·53
Al_2O_3	15·35	17·34	19·74	15·25	16·88	13·06	18·36	13·44	15·87	13·60	16·21	9·15	12·68	7·99	6·88
Fe_2O_3	3·61	6·32	3·10	8·22	4·99	6·77	10·30	5·32	4·10	1·86	3·44	1·41	1·10	----	0·59
FeO	9·57	4·62	5·71	7·19	5·56	5·36	----	8·96	7·58	8·61	4·63	4·12	1·86	3·35	4·11
MgO	7·83	4·93	8·24	5·96	7·89	4·10	5·49	4·21	7·53	6·26	4·99	3·04	0·48	1·54	1·86
CaO	4·37	13·07	4·63	11·32	11·15	11·65	11·03	5·80	9·06	10·97	3·82	2·84	1·40	1·10	0·68
Na_2O	3·22	2·95	3·57	2·11	3·20	3·35	1·12	3·73	3·59	3·09	5·36	2·24	1·61	5·97	1·21
K_2O	2·68	0·25	0·51	0·56	0·46	0·57	0·11	1·71	0·54	0·12	0·39	0·43	0·76	0·22	1·24
H_2O 110°+	4·25	1·48	5·89	2·13	1·81	1·39		3·42	1·07	3·84	0·98	2·06	1·03	0·74	1·35
H_2O 110°—	0·16	0·08	0·16	0·04	0·17	0·12	4·20	0·36	0·16		0·22	0·08	0·12		0·07
CO_2	1·05	2·24	trace	----	----	2·97		none	none	----	----	----	none	----	----
TiO_2	1·63	0·85	1·36	not det.	----	2·14	0·45	3·90	1·19	1·31	1·37	----	0·17	----	----
P_2O_5	----	----	----	----	0·14	----	trace	----	----	0·21	----	----	----	----	----
MnO	trace	trace	trace	trace	0·56	0·09	----	trace	trace	0·04	trace	trace	trace	----	trace
	100·09	100·52	100·27	100·25	100·65	99·46	99·73	99·73	99 84	99·59	99·67	99·85	100·64	101·12	100·52

I. Epidote-glaucophane schist. Winston's Bridge, near Roseburg, Oregon. Washington anal.

II. Epidote-glaucophane schist. Kyperusa, Syra. Washington anal.

III. Epidote-glaucophane schist. Srnjcovacki Potok, Fruska Gora Croatia. Washington anal.

IV. Epidote-glaucophane schist. The Monument, Anglesey, Wales. Washington anal.

V. Garnet-glaucophane schist. Pine Canyon, Mt. Diablo, Cal. Melville anal.

VI. Epidote-glaucophane schist. Norimoto, Mikawa, Japan. Washington anal.

VII. Epidote-glaucophane schist. Val Maira, Piedmont. Aichino anal.

VIII. Glaucophane "Slate." Kamoi Kotan, Hokkaido, Japan. Washington anal.

IX. Garnet-glaucophane schist. Tupper Rock, Bandon, Coos Co., Oregon. Washington, anal.

X. Zoisite-glaucophane schist. Sulphur Bank, Cal. Melville anal.

XI. Mica glaucophane schist. Cafe Skarbeli, Hermoupolis, Syra. Washington anal.

XII. Quartz-glaucophane schist. Santa Catalina Island, Cal. Washington, anal.

XIII. Quartz-glaucophane schist. Mt. Kappari, Syra. Washington anal.

XIV. Quartz-albite-glaucophane schist. Angel Island, Cal. Ransome anal.

XV. Quartz-glaucophane schist. Four Mile Creek, Coos Co., Oregon. Washington anal.

Comparisons with other rocks.—Rosenbusch* has already called attention to the fact that "certain glaucophane rocks are chemically identical with the igneous rocks belonging to the gabbro magmas, or their tuffs." He bases this conclusion on the two analyses of Melville (Nos. V and X), admitting at the same time that it does not follow that all glaucophane rocks are so derived.

That this main conclusion is correct for the majority of glaucophane schists would seem to be borne out by the analyses in the table, and their comparison with typical analyses of diabase and gabbros quoted in the large works of Roth, Zirkel and Rosenbusch. It is undeniable that there is a remarkably close agreement between the two, and the conclusion is irresistible that a large part of the glaucophane schists are probably derived from diabases, gabbros or their tuffs.

That this is not true of all is rendered certain by the four analyses of acid glaucophane schists, which we have already seen are in all probability derived from cherts, quartzose shales or quartzites. The anomalous analysis No. XI corresponds with those of many rather acid diorites, and it is possible that it has been derived from a rock of this kind, though this is not certain.

Although outside the scope of this paper it will not be amiss to call attention to several cases which bear directly on the question of the derivation of some of the glaucophane schists from rocks of the gabbro family, and which are strongly confirmatory of this view.

Direct evidence of the change from undoubted igneous rocks was first given by Kotô† in the case of several Japanese occurrences, melaphyrs and diabase tuffs showing a gradual increase in the blue amphibole and final transition into true glaucophane schist, through "glaucophanization" of the diallage. Instances of the same thing are also mentioned by Harada.‡

Another instance is furnished in Greece by Lepsius, in his description of the metamorphic schist of Attica.§ He shows that some of the gabbros of this region, which have been intruded into the sedimentaries and have been subjected to the same regional metamorphism, contain glaucophane, often in large quantities, though there are apparently few instances of the final conversion into true glaucophane schist.

It may be noted that the gabbros from near the Isthmus of Corinth and from Argolis, according to Lepsius and my own observations, do not show any glaucophane, but are analogous

* Rosenbusch. op. cit., p. 711.
† Kotô op. cit.
‡ Harada, op. cit., p. 62.
§ Lepsius, Geologie von Attika. Berlin, 1893, p. 176.

to a more basic group of gabbros, also occurring in Attica, which furnish serpentine on alteration.*

The Attic Cretaceous shales, according to Lepsius,† also yield glaucophane schists as products of metamorphism. Unfortunately no analyses are given, but some of them, as that from Velaturi near Thoriko, must resemble closely the Kyperusa schist, being composed essentially of glaucophane and epidote. Others again are more acid and carry along with glaucophane abundant quartz, feldspar and white mica.

In this connection it is of interest to note that glaucophane schists are very common in the whole region of metamorphic rocks which runs along the eastern coast of Greece, and extends southward and eastward through the Archipelago. Rocks of this character have been described from Thessaly,‡ Euboea,§ Attica,‖ Thermia,¶ Tinos,** Siphnos,†† Syra, Milos,‡‡ Samos,§§ Rhodes,‖‖ and Smyrna.¶¶

We have already seen that the glaucophane schists of Anglesey are probably derived from diorite (possibly gabbro), since, according to Blake and Harker, gradual transitions are observed from massive diorite to hornblende schist, the glaucophane schist being locally developed. Serpentine also occurs on Anglesey, though not near the Monument, where diorite occurs.*** Though the whole district has been subject to regional metamorphism,††† it is uncertain whether the development of glaucophane schist is due to this or to contact metamorphism.

Another instance of derivation from basic igneous material is that given by Rosenbusch in the paper already cited. He describes specimens sent by Palache, labelled "altered tuff" from near Berkeley, Cal., and concludes that these diabase tuffs do in fact alter to true glaucophane schists.

In his monograph on the Quicksilver Deposits of the Pacific Slope Becker‡‡‡ briefly describes the alteration of diabase to glaucophane schist, and also speaks of the glaucophane schists of Mt. Diablo passing over into slightly altered shales.

* Lepsius, op. cit., p. 86.
† Lepsius, op. cit., pp. 133 and 136 ff.
‡ F. Becke, Min. Petr., Mitth., vol. ii, p. 49, 1879.
§ F. Becke, op. cit., p. 71.
‖ Lepsius, op. cit.
¶ Oebekke, Zeitschr. d. d. Geol. Ges., vol. xxxviii, p. 644, 1886.
** Von Foullon and Goldschmidt, op. cit., pp. 24 and 31.
†† K. Ehrenburg, Inselgruppe von Milos. Leipzig, 1889, p. 101.
‡‡ I. Chelussi, Giorn. di Min., vol. iv, p. 34, 1893.
§§ Foullon, Sitzber. Akad. Wiss. Wien, vol. c, p. 176, 1891.
‖‖ Oebekke, op. cit., p. 651.
*** Cf. Blake, Q. J. G. S., vol. xliv, pl. xiii, 1888.
††† Sir A. Geikie, Anc. Volc. of Gr. Brit., vol. i, pp. 128, 220, 1897.
‡‡‡ Becker, op. cit., pp. 100 and 102.

Finally Barrois* regards the glaucophane schists of Île de Groix, in Brittany, as the product of the metamorphism of sedimentary rocks.

Comparison with amphibolites.—A point of some interest, already touched on by Rosenbusch,† is the general similarity in chemical composition between the basic glaucophane schists and many of the amphibolites, as may be seen on reference to the analyses of these last given by Roth, Zirkel and Rosenbusch. It was hoped that the present investigation would throw some light on this point, and possibly reveal some constant difference in chemical composition between the two, which would serve to explain the diverse mineralogic resultants of apparently identical metamorphic processes on similar original material.

The results are, on the whole, inconclusive, though as a rule, the amphibolites are higher in MgO, CaO and K_2O, and lower in Fe_2O_3, than the glaucophane schists. The eclogites approach, as a class, much more closely to the glaucophane schists, especially in low K_2O, though they also are apt to be higher in MgO and lower in Fe_2O_3.

As Rosenbusch remarks, the distinction between the amphibolites and the glaucophane schist lies in the fact that, while in the former the Na_2O has gone into feldspar, in the latter it has gone into glaucophane. He suggests that this may be connected with a difference in the age of the rocks.

With this view I cannot agree. It seems more reasonable to suppose that, just as in the consolidation of igneous magmas the eventual mineralogic composition of rocks derived from any given magma is chiefly dependent on the physical conditions of cooling, the presence of mineralizers, etc., so here physical or chemical conditions have determined whether the metamorphism of, for instance, a diabase tuff produces a normal amphibolite or an epidote-glaucophane schist.

This view is based partly on the general reasoning which has abolished the age distinction in igneous rocks, and partly on the following considerations:

In the first place, we find at many places, as Île de Groix, Greece, California, Anglesey, etc., amphibolites and glaucophane schists occurring together, the latter being often only locally developed.

In the next place glaucophane has been often developed at one locality by the metamorphism of such widely diverse original materials as cherts and diabase tuffs. This points clearly to the existence of some peculiar conditions, apart from

*Barrois, Ref. Neus Jahrb., 1884, ii, p. 72.

†Rosenbusch, op. cit., p. 711.

the composition of the original material, as necessary to the formation of the mineral.

Again we find glaucophane schists in the "Grundgebirge" or Lower Cambrian at Île de Groix, Neocomian among the Pacific Coast, Post Cretaceous in Attica, and probably of other ages elsewhere. Similarly amphibolites are found of various ages.

Lastly, the fact that these rocks are not found generally distributed over the earth, as are the amphibolites, but occur in well-defined zones or regions of metamorphic rocks, points to the existence of some peculiarity in the conditions of the metamorphic processes involved. This occurrence in strongly marked regions is exemplified by their presence in Greece and the Archipelago, the Piedmont Region in Italy, Japan and along the Pacific Coast of this country.

Summary.—The glaucophane schists belong to two main groups, sharply separated from each other. The larger one is basic, composed chiefly of glaucophane and epidote, often with abundant garnet, zoisite, diallage, and sometimes smaller amounts of mica, feldspar and quartz, and rutile and titanite as frequent accessories. Chemically these closely resemble the composition of the rocks of the gabbro family, and are apparently divisible into two subgroups, one high in CaO, the other low in it. These are in most cases almost undoubtedly derived from such igneous rocks or their tuffs, but also possibly in rarer cases from sediments or slates of similar composition.

These basic glaucophane schists scarcely differ in chemical composition from the amphibolites and eclogites, and the difference in their formation is probably to be ascribed to differences in the conditions of metamorphism.

A smaller, but widely spread, group is acid in composition, and these are composed largely of quartz and glaucophane, with mica and sometimes albite. These are derived from cherts, quartzites or quartzose shales and sandstones.

The existence is indicated of a third, still smaller, group of intermediate mineralogical composition, and chemically like the diorites.

The glaucophane schists are apparently the result of both regional and of contact metamorphism, and in many regions they occur together. This last seems to be the rule in glaucophane schist areas of any size, and where only the one kind is found the area is apt to be small.

Locust, N. J., September, 1900.

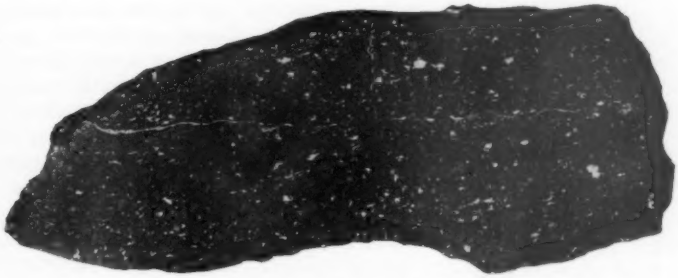
ART. IV. — *On the Nature of the Metallic Veins of the Farmington Meteorite;* by O. C. FARRINGTON.

IN notes on the Farmington, Kansas, meteorite published some years ago,* Preston described numerous metallic veins occurring in the mass of the meteorite, and made the following suggestion as to their origin: "That, as the meteor struck our atmosphere the concussion was so great that the mass was fractured in various places, of course extending from the surface inward, and the larger of these fissures or fractures were then filled by the metallic iron which was fused on the exterior surface of the mass, due to its velocity through the atmosphere and was thus forced in a molten state into its present position, thus forming the metallic veins." The explanation is ingenious and perhaps correctly states the origin of the veins, but a recent study of the matter by the writer has led him to a somewhat different conclusion.

A discussion of the point seems desirable in view of the light it may throw on the question as to whether the veins of meteorites are in general of terrestrial or pre-terrestrial origin. It should be first noted that the formation of fractures or fissures in a meteoric mass ought not probably to be ascribed to concussion from the meteor striking our atmosphere. The fact that such crumbly and friable meteorites as Orgueil, Warrenton, Allegan and others have reached the earth intact seems to argue against there being any particular force of concussion attending the meeting of a meteorite with the earth's atmosphere. The resistance of the atmosphere to the passage of a meteorite is probably rather a gradually increasing one. In the writer's view, therefore, expansion due to external heating of the mass while the interior remained cold is the cause of any fissures which may form in a meteorite during its passage to the earth. Granted, however, that such fissures may form the above quoted explanation of the metallic veins seems to be open to two objections: 1st. The interior of a meteoric mass of any considerable size is so cold that portions of molten metal would be chilled before penetrating to any appreciable distance. 2d. The metallic constituents of the Farmington meteorite are its least fusible ones. That the interior of a meteorite may remain intensely cold during its fall to the earth has been proved in at least two instances, that of the Dhurmsala meteorite, the fragments of which were so cold as to benumb the fingers of those who picked them up, being the

* This Journal, III, xliv, p. 399.

best known. The fact has already been urged by Tschermak* as proof that Reichenbach's view that the black veins of meteorites are formed by the flowing of fused material of the crust into fissures, cannot be correct, and he notes that in the Chantonnay meteorite the fused matter of the crust only penetrated the fissures to a depth of 6^{mm} even though they were open some distance beyond this. Moreover the Farmington meteorite was not hot when dug up four hours after its fall.† The veins of other sections of the Farmington meteorite have less the appearance of leading in from the surface than those figured by Preston. In a section now in the Field Columbian Museum collection, shown in fig. 1, two veins cross one another nearly at right angles. One of these is continuous at intervals



Farmington meteorite, natural size.

for a length of 90^{mm}. It is hard to conceive of such a system of fissures as this filling from the surface.

That the nickel-iron of the Farmington meteorite is more difficultly fusible than the stony constituents is proved by the fact that the former stands out in many places over the surface in prominent rounded beads. If any material had flowed into the fissures, therefore, it would probably have been fused silicates. If then the above theory of the origin of the metallic veins cannot be accepted, what is their nature? They do not appear to be of the nature of the *harnischflächen* of the Honolulu, Möcs, Pultusk and other meteorites, which when seen in cross section look like metallic veins but when cleft along the vein are plainly seen to be slickensided surfaces over which movement has flattened and drawn out the metallic grains. In the view of the present writer the veins of the Farmington meteorite are phases of structure of the metallic constituents of the mass. It is well known that the structure

* Sitzb. Wien. Akad., 1874, lxx, p. 467.
† Science, vol. xvi, p. 39.

of many of the siderolites is that of a metallic network enclosing grains of the silicates, while on the other hand the tendency of the metallic grains of many aerolites to a continuous arrangement has been noted by Reichenbach* and Newton.†

Between meteorites of the siderolite structure and those in which the metallic constituents occur only as isolated grains there are all gradations. Hence sheets or filaments of a continuous network might remain in some portion of a meteorite, while in the remainder the metallic constituents would be present only as isolated grains. Favorable cross sections of a continuous network would appear as veins. Metallic filaments which are undoubtedly of this character are to be seen in sections of the Crab Orchard (Rockwood) and Bluff meteorites now in the Field Museum collection. The nickel-iron appears in general in the sections in the form of isolated grains, but over a portion it appears as continuous filaments. These are the only sections in the collection which show such filaments but there is every reason to believe that the filaments could be found on sections of other meteorites if looked for. If the writer's view be correct, therefore, the term filament would describe these structures better than the term veins, since the latter term implies fissures filled subsequent to their origin.

* Pogg. Annalen, vol. cviii, pp. 291–311.
† This Journal, III, xlv, p. 152.

Field Columbian Museum,
Sept. 1, 1900.

ART. V.—*Erigenia bulbosa* Nutt. A morphological and anatomical study; by THEO. HOLM. (With six figures in the text.)

WHILE not especially interesting in morphological respects, the *Umbelliferæ*, nevertheless, possess types which have attracted some attention, though more by the structure of their flowers and inflorescence than by their vegetative organs. The seedling-stage, with the first development of rhizome and roots, has been studied in only a relatively small number of species by Bernhardi, Hegelmaier, Irmisch, Klebs, Lubbock, Winkler and others, and in regard to the mature plants, there are many species, which are so little known that it is altogether conjectural whether their underground organs represent roots or rhizomes; even in the "Revision of North American *Umbelliferæ*" * the authors have made no attempt to draw the distinction between roots and rhizomes, but state simply: "We use roots here in the ordinary systematic way. Morphologically these tuberous roots are mostly subterranean stems." Considered from an anatomical view-point the order seems to be known much better, and we find in the literature several papers with accounts of the anatomy and some very comprehensive studies of the oil-ducts, which are particularly well developed in this order (*Umbelliferæ*).

Thus it would appear as if there were a number of vacant spaces to be filled in the life-history of the order, and it is, therefore, our intention to present some brief notes as a contribution to the knowledge of one of its members, the "Harbinger of spring": *Erigenia bulbosa*.

It is a plant, which has, for a long time, attracted our attention on account of its globular underground part, by Nuttall correctly defined as a tuberous root. Having made a special study of similar plants with tuberous, underground parts, we have often desired to ascertain how far *Erigenia* possesses a true tuber or a tuberous root. It is, however, not always satisfactory to study plants of this nature only from adult specimens, and the publication of observations of this plant has been postponed for a considerable period until we succeeded in obtaining material in the seedling stage. The seedlings are, as a matter of fact, not easily found, and it was not until last spring that we detected some young plants, which proved to be the seedlings of *Erigenia*. Several years ago, in the early spring, we collected quite a number of seedling plants with only one cotyledon, just as we expected to find in *Erigenia*,

* For references consult the Bibliography appended to this article.

but an anatomical study of the specimens proved these to be seedlings of *Claytonia Virginica*, which germinates with a single cotyledon. But those of *Erigenia*, which we found last spring, did not only exhibit a single cotyledon, but they showed besides all the anatomical details, the characteristic oil-ducts for instance, as were familiar to us from the study of full-grown individuals; moreover these little seedlings showed a minute tuberous body at the base of the cotyledon.

Erigenia bulbosa seems to be rare in the vicinity of Washington, D. C., and has so far only been recorded from High Island and Plummer's Island; it is also found on the muddy river shore at Great Falls, Maryland, where we discovered it a few years ago. It prefers low, shaded grounds, and was found associated with such plants as *Dicentra*, *Trillium*, *Caulophyllum*, *Jeffersonia* and *Erythronium*. It may be found in bloom as early as the month of March or the beginning of April, and the seedlings appear at the same time. It is by no means acaulescent, but the stem is very low and bears a few stem-leaves and umbels, which are held in an erect position during anthesis. In the fruiting stage the stems bend down towards the ground, though without burying the fruits. These are said to fall off before maturity, a statement we cannot confirm, at least not according to our own observations. The seedlings are small, but occur in large numbers with the older plants, and the color of the cotyledonar leaf-blade is of the same deep green as the leaves of mature specimens. The blade of the cotyledon is held in a horizontal position, raised above the ground by a long, slender petiole (fig. 1). As already stated, a small light brown, tuberous body is to be noticed at the base of the cotyledon and this is the first indication of the globular root, which represents one of the characters of the genus, the monotypical *Erigenia*.

The tuber is at this stage about 2^{mm} in length, and tapers almost gradually into a filiform, unbranched root, covered by root-hairs, which are not very numerous, however. We observed, on the other hand, no root-hairs on the tuber itself and suspected, thus, that it represented the hypocotyl, but by examining its internal structure we felt convinced that it actually represents the basal portion of the primary root itself; the filiform part of the root does not grow out any further, but dies off during the first season. No other leaf than the cotyledon develops in the first year, and the plumule stays underground concealed in the sheathing base of the cotyledon. In the month of May the cotyledon had already faded away entirely, and the same was, also, the case with the leaves and stems of older specimens. In the second year after germination has taken place, the first proper leaf pushes up through

the ground (fig. 3) and shows a small, ternately decompound blade with divisions of the same shape as those of mature leaves. This leaf has during the winter been surrounded by a small, membranaceous, scale-like leaf, which is still to be seen at this stage, but is, however, mostly decayed and not plainly visible. The tuber has increased in thickness, and the filiform part of the root below the tuber has died off altogether. A few (three or four) lateral roots, all filiform, have developed

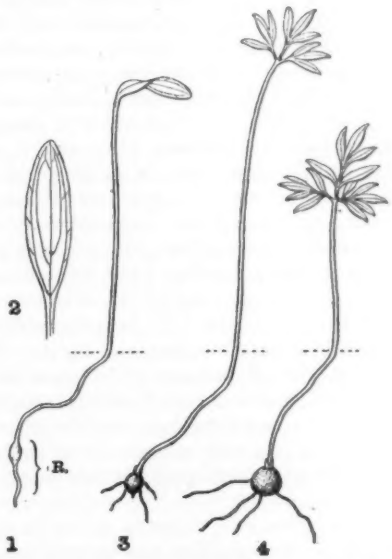


FIG. 1. Seedling of *Erigenia bulbosa* Nutt.; natural size. R = the primary root.

FIG. 2. Blade of the cotyledon, enlarged.

FIG. 3. Young plant in its second year; natural size. The filiform portion of the primary root has faded away, and four lateral roots have developed from the tuberous part. A small scale-like leaf is to be seen at the base of the petiole of the green leaf.

FIG. 4. Young plant in its third year; natural size. The dotted lines indicate the surface of the soil.

from the sides of the tuber, but otherwise the plant does not show much progress in growth since the first year. The third year's growth is not much advanced either (fig. 4), as only one green leaf is developed, though with a few additional divisions of the blade, and we find, also, at this stage a small scale-like leaf at the base of the larger, which has, thus, served as bud-scale during the winter. The tuber has only grown very little, retaining its globular shape and brown color, but no additional

lateral roots were observed at this stage. The depth of the tuber is, however, changed, and it seems as if it becomes buried deeper and deeper in the ground every season, not by means of contractile roots, but by continued deposits of sediment from the river during the winter, when the localities become inundated.

Erigenia thus germinates with only one cotyledon and the basal portion of the primary root shows a distinct swelling during the first year. This manner of germinating very much resembles that of *Carum Bulbocastanum*, which according to Irmisch's observations does not develop more than one cotyledon, the other one staying as rudimentary, but observable in the seed itself. Adventitious roots develop sometimes from the base of the cotyledonar petiole in this species of *Carum*, and similar roots have, also, been observed upon the underground portion of the hypocotyl in *Chærophyllum bulbosum*. In *Erigenia*, however, we found no seedlings, where such adventitious roots had developed from the base of the petiole. Some of the other *Umbelliferæ* exhibit, also, a somewhat singular manner of germinating, viz: *Smyrnium olusatrum*, in which the hypocotyl is very short, while the cotyledonar petioles form a tube of 8–15^{mm} in length, which the plumule has to penetrate in order to reach the light. *Ferula Candelabrum* and *Tordylium Syriacum* illustrate a similar germination, but the cotyledonar tube is much shorter in these; *Ferulago*, *Prangos*, *Chærophyllum bulbosum* and *Smyrnium perfoliatum* possess also a cotyledonar tube, and the cotyledons are in the two last named the only assimilating organs of the plant during the first year.

In returning to *Erigenia*, there is, as we have stated above, a regular succession of scale-like and green leaves, which continues for about four years; after that time there may be developed two or three scale-like leaves, while at the same time the aerial leaf has attained the same size and shape as the later developed stem-leaves. The plant does not seem to reach its flowering stage until about six or seven years after the seed has germinated, and the flowering stem is in its bud-stage protected by about four scale-like leaves, tightly enclosing each other. When we, therefore, examine a flowering specimen of *Erigenia*, we find only scale-like leaves at the apex of the tuber, and the first green leaf at this stage is situated upon the stem some distance from the tuber, but close to the surface of the ground. The distance from the tuber to the first green leaf varies very much and depends of course upon the depth of the tuber in the ground; we observed specimens in which this stem-internode was only 1 or 2^{cm} in length, while in others it reached 13^{cm}. In most cases only a single stem is

developed during a season; this is terminal, but it is not unusual to find two or three more, which are lateral and developed from the axils of the scale-like leaves. Whether the plant produces flowers more than once is a question, which we have not been able to answer, since no traces of flowering stems from previous years were observed upon the large tubers, a fact that does not, however, exclude the possibility of the plant having bloomed before, inasmuch as the stems are so very weak and evidently fade away entirely. The tubers of fruiting specimens showed no signs of losing their vitality, but were, on the contrary, in perfectly healthy condition and still containing considerable deposits of starch: hence we suppose that *Erigenia* may be considered as a polycarpic plant.

While *Erigenia* is quite interesting at the seedling- and succeeding stages, when compared with the majority of the *Umbelliferæ*, hitherto examined from this viewpoint, there are, furthermore, some peculiarities in its internal structure, which may be mentioned in connection therewith. Moreover it has not been possible from a mere superficial examination to decide whether the tuberous body is a true tuber: a stem-part, or simply a swollen root. The fact that we found no root-hairs on the tuberous part, but only on the filiform part, does not seem sufficient for separating them as morphologically distinct from each other, the former to represent a stem, for instance the hypocotyl, the latter a root. An anatomical study is necessary to decide this question, and since *Erigenia* does not appear to have been examined anatomically, it may be well to add some other details in regard to the position of its oil-ducts for instance, which are very distinct and well developed in this genus.

If we examine one of the filiform roots of a tuber in its third year, we find the following structure: Epidermis, this is almost without roothairs, but many of the cells exhibit a slight extension of the outer wall, though not enough to form what is generally termed as "papillæ"; the cortical parenchyma is thin-walled and composed of a few (four or five) strata without deposits of starch, and, furthermore, neither lacunes or oil-ducts were observed in this tissue. The endodermis (E in fig. 5) is thin-walled and shows the dots very plainly; inside the endodermis is a pericambium of only one layer which surrounds the leptome and hadrome.

The hadrome constitutes a diametrical band of vessels, corresponding to two hadromatic rays of which the outermost (the first developed) are narrower than the inner. On each side of this single row of vessels is a group of leptome and separated from these by a stratum of thin-walled conjunctive tissue. Two, in transverse section, rhombic ducts (D) are

visible in the pericambium itself, just outside each of the two oldest vessels, hence diametrically opposite each other. The center of the root is occupied by a very wide vessel. If we compare this structure of a lateral root with that of the filiform, primary root of the seedling, we notice the same arrangement and development of tissues with the single exception that there is no central vessel in the primary root, but the two rows of vessels are separated from each other by conjunctive tissue. The primary and the lateral roots thus show the same principal structure and, as we have stated above, none of the tissues showed signs of contractility.

5

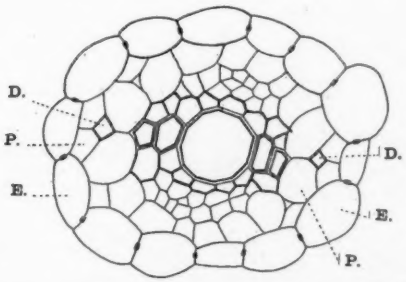


FIG. 5. Transverse section of the inner part of a lateral root of *Erigenia*. E = endodermis; P = pericambium; D = the ducts, developed in the pericambium. There is a group of leptome on each side of the diametrically arranged vessels, separated from these by a layer of conjunctive tissue. × 560.

If we, now, examine a series of sections, taken from various parts of the tuber itself (the seedling-tuber), we observe the following modifications. In sections taken from a little above, where the filiform root begins, the structure is identical as far as concerns epidermis, cortex and endodermis, the two latter however, containing deposits of starch. The pericambium, on the other hand, shows a number of cell-divisions and consists, thus, of several layers, surrounding the two rays of hadrome and the leptome, situated as described above. In other sections taken from the thickest part of the same tuber, the structure is still more different, but illustrates, nevertheless, a root-structure. Epidermis, cortex and endodermis are, still, preserved, but the endodermis surrounds now a mass of parenchyma, filled with starch, which borders inwards on several strata of cambium, which lies close to a central group of vessels, arranged in a line, just as we observed in the filiform root. There is no pith, and the leptome shows the same position as before, but is separated from the vessels by the cambium.

Several ducts, rhombic in transverse sections, occur inside the endodermis as a peripheral band around the central-cylinder. The increase in thickness, at this part of the seedling-tuber, is then due not only to the pericambium, which has now developed a broad parenchyma, a secondary bark, but also to the formation of a cambium between the leptome and hadrome. The tuber as it appears during the seedling-stage is thus to be considered as a swollen part of the primary root, of which the structure has been modified somewhat by the divisions of the pericambium and by the formation of cambial strata. The divisions of the pericambium have not, however, ceased at this moment, but continue during the further growth of the tuberous root-part. If we, for instance, examine another specimen in its third year, we notice that the epidermis, the cortex and endodermis have been thrown off, while the pericambium, by outward divisions has begun to develop a number of cork-layers at the same time as it continues the formation inwards of secondary cortex.

While thus the anatomical structure of the primary root is readily recognized as that of a true root in its entire length, in its tuberous and in its filiform part, and well comparable with that of a specimen in its third year, we find in fully matured specimens, such as have reached the flowering stage, a very different structure, which may have led to the belief that the so-called "globular tuber" is a stem and not a root; that is supposing a study of the seedling-stage to have been omitted. The mature tuberous root possesses a number of cork-layers, a secondary bark of very considerable width, filled with starch, and inside the bark is a band of collateral mestome-bundles with cambium between the leptome and hadrome and besides well defined strata of interfascicular cambium, while a broad pith occupies the central portion of the root, of which, however, the innermost part is broken down into a cavity; thus the principal features of the primary root are, almost, totally obliterated. Oil-ducts are quite numerous in the mature root; they are located in the same radii as the mestome-bundles and occur in four or five concentric bands. The innermost oil-ducts are to be seen in the leptome itself, the others some distance apart, the outermost being very near the periphery, though not in contact with the cork. It appears as if the ducts of the outermost two bands are mostly pentagonal in transverse sections, while those of the inner are rhombic and somewhat narrower in circumference.

Having thus described the root-system of *Erigenia*, we might, also, give a few notes on the structure of the other organs, as these are developed in the seedling and the mature plant. The petiole of the cotyledon exhibits the same pecu-

liarity as seems characteristic of the *Umbelliferæ* in general, i. e., the mestome-bundles are separated from each other, and in this genus they are arranged in the form of an arch; there is no collenchyma; ducts with four special cells occur in the leptome besides that a larger duct with six special cells is to be observed beneath each of the three mestome-bundles on the leptome side. The leaf-blade of the cotyledon shows a bifacial structure with stomata on both faces, most numerous on the lower surface; a palisade-tissue of one stratum occupies the upper part of the blade, while an open pneumatic tissue occupies the lower. Large ducts with six special cells are visible above and below the mestome-bundles, but neither the smaller ducts, rhombic in transverse section, or collenchyma were found at this stage. In the petiole of a large leaf taken from a flowering specimen, there are five isolated mestome bundles forming an arch as in the cotyledon, and we noticed eleven oil-ducts, all of which were large and surrounded by five or seven special cells; these ducts are located in the cortical parenchyma, and mostly separated from the epidermis by a small group of collenchyma. The blade of the mature leaf has stomata only on the lower surface, and the cells of epidermis on the upper face are extended into minute, roundish papillæ, which along the margin attain the shape of pointed, thick-walled prickle-like projections. Otherwise the structure is like that of the cotyledon, and oil-ducts, were, also, found here above and below the mestome-bundles.

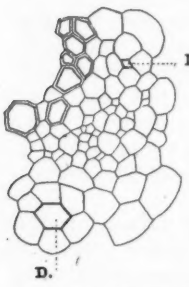


FIG. 6. Transverse section of a part of a mestome-bundle of the cotyledonar petiole of *Erigenia*. Two ducts (D) one with four, the other with six special cells. × 400.

The stem above ground is obtusely triangular in transverse section and shows a rather weak structure with only moderately thick-walled collenchyma in small groups, inside of which we noticed the usual large ducts as in the petiole. But we found, also, the smaller ducts, and these occurred in the leptome, one on each side of this. Five mestome-bundles surround a thin-walled pith, of which the innermost portion is broken down, leaving a wide cavity in the middle of the internode. While oil-ducts are known to occur in the pith of several genera of this order, it seems as if they were lacking in *Erigenia;* we were, at least, unable to find any of these ducts in the pith in spite of very careful research.

The peduncle of the umbel is quadrangular in outline and the angles are rough from the presence of small prickle-like

projections from the epidermis, which is, here, distinctly thick-walled and covered by a wrinkled cuticle. There are four groups of collenchyma, one in each angle, corresponding to four mestome-bundles and four large oil-ducts, located in the bark, between the collenchyma and the mestome-bundles. The cortical parenchyma is somewhat open and consists only of about four or five layers, bordering on a thin-walled but solid pith. None of the smaller ducts with four special cells were observed in the peduncle, although we had expected to find such in the leptome, inasmuch as they were observed in the main stem.

In regard to the anatomical structure of the fruit, we observed that the carpophore is developed as a thick coating on the concave, ventral face of each mericarp and adnate to these. Thirty-eight oil ducts were noticed in each mericarp: twelve on the commisural side, one outside each of the five mestome-bundles and from five to six in the intervals between these. The statement by Coulter and Rose that the number of oil-ducts in the mericarp of *Erigenia* is only "one to three in the intervals and nine to eleven on the commisural side," is not correct; the same is also the case with the description of the ducts as being developed in "the inner epidermal layer itself." They are, according to our observations, developed in the mesophyll, but their location can only be ascertained by examining mericarps, which are not fully matured. We might furthermore, state that the mericarps are not glabrous, but hairy from numerous, short, unicellular, pointed hairs, which are readily seen to cover the entire dorsal face of these.

Brookland, D. C., May, 1900.

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Art. VI.—*New Species of Merycochœrus in Montana.* Part II. By Earl Douglass.

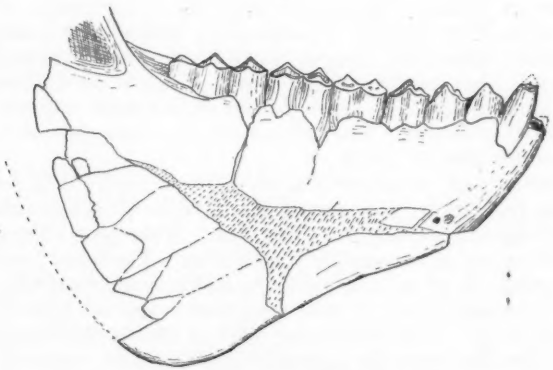
Merycochœrus altiramus n. sp.

This species, from the Madison Lake beds of the Loup Fork epoch, is represented by a right mandibular ramus which only lacks the posterior border and some other small fragments. The jaw is nearest like that of *M. laticeps*, but differs from it in several respects. In the present species the lower border slopes more uniformly downward and backward from the chin. From *pm 4* backward the jaw is deeper. I know of no other that is as deep in proportion to the length. The greatest depth, back of *m 3*, was very nearly $\frac{3}{5}$ the greatest length. The symphyseal border, at least the lower portion, was not concave and it forms a larger angle with the lower border of the jaw than in *M. laticeps*. The concavity under *pms 3* and *4* is less and the masseteric fossa is much deeper, being bounded in front by a high narrow ridge which dies out on the alveolar border under *m 3*. The lower border of the fossa is about on a line with this border. There is a small *foramen mentale* under the posterior part of *pm 3*.

Dentition.—A small portion of the bone in front of *pm 1* is lost, but the lower portions of the alveoli of the canine and first and second incisors are preserved. There is no trace of a first incisor and there probably was none. The inner border of the alveolus of *i*2 is only about $1\frac{1}{2}$ millimeters from the symphysis. Separated by a still narrower ridge of bone is the alveolus of *i*3. One millimeter back of this is the three-sided canine alveolus with its rounded angles. The posterior side was the broadest and is close to *pm 1*. The canine was much smaller than the first premolar. The first premolar is set diagonally in the jaw. In cross-section it is nearly lenticular but the anterior inner side is concave, while the greater inner convexity is farther back than the outer one. Its transverse to its antero-posterior diameter is as 11 to 17. Its anterior and posterior edges are thin and sharp, and, though the tip is broken off it evidently ended in a sharp point. *Pm 2* is thin, compressed and trenchant and like the first is inserted diagonally but with two roots. It is almost unworn. The highest point and the convexity that descends from it are in the median line, but the posterior slope is steeper and longer. As seen from above the crest is sigmoid. In front of the highest point there is a hint of the anterior inner lobe that is quite prominent in *pms 3* and *4*. Back of this is a small groove. On the posterior inner side of the tooth is a slight concavity,

and another faint depression on the posterior outer surface. On the posterior margin the descending ridge divides, forming a little delta. In the third premolar these points are all more prominent and the posterior internal concavity has become quite a deep fossa bounded anteriorly by a prominent ridge. In *pm 4* the ridge has become a prominent element of the tooth, being separated from the other part by a large posterior fossa and the extension backward to meet it of the anterior interior fossa. In this tooth the posterior concavity above mentioned has become quite a deep trough and is more nearly central. The unworn and nearly perfect condition of the premolars gives an excellent opportunity for the study of their development and their conditions before wear. If worn to the same extent they would not differ so greatly from those of *M. laticeps*.

1.



Merycochœrus altiramus, $\times \frac{1}{1}$.

Measurements.

	M.
Inferior dental series, length	·163
Molar-premolar series, length	·158
Molar series, length	·098
Premolar series, length	·060
First lower premolar, length, greatest	·018
First premolar, width, greatest	·011
Second lower premolar, length	·017
Second lower premolar, width	·008
Second lower premolar, height	·013
Third premolar, length	·019
Third premolar, height	·015
Fourth premolar, length	·019

	M.
Fourth premolar, width*	·0085
First molar, length	·0224
First molar, width*	·0126
First molar, height	·015
Second molar, length	·028
Second molar, width	·013
Second molar, height	·0245
Third molar, length	·0446
Third molar, width	·011
Depth of ramus beneath pm2	·042
Depth of ramus beneath pm 4, middle	·053
Depth of ramus beneath m1, middle	·063
Depth of ramus beneath m2, middle	·076
Depth of ramus beneath front part of m3	·098
Depth of ramus beneath back part	·125

Found by the writer in layer of sand at bottom of Loup Fork beds near top of White River beds in bluffs on eastern side of Lower Madison Valley about ten miles from Three Forks, Gallatin Co., Montana.

Merycochœrus madisonius n. sp.

In my collection from the Madison bluffs is a lower jaw fragment with the anterior lobe of *m 3*, *m 2*, *m 1*, the roots of *pms 4* and *3* and of *pm 1*. It represents a somewhat older but smaller animal than the one described as *Merycochœrus laticeps*, from which it differs in several particulars. The corresponding part of the ramus is much shorter. The anterior part has about the same depth. There is not that sudden descent under the interval separating *m 2* and *m 3*, to form the rounded angle. The *foramen mentale* is larger, narrower, and situated relatively farther back, being mostly under *pm 4*. The posterior part of the symphysis is farther back, being beneath the interval between *pm 4* and *m 1*. The ramus is much thicker near the lower border under *m 1*, the two being in the proportion of 19 to 24. The lower border is preserved to a point beneath the front lobe of *m 3*. Here it is much narrower than in *M. laticeps*, being $\frac{3}{4}$ the width. As nearly as I can determine the length of the premolar series and the first two molars in the present species is $8{\cdot}8^{cm}$; in *M. laticeps* it is $10{\cdot}3^{cm}$.

The length of the premolars and first two molars is about the same as in *M. rusticus*. The *foramen mentale* is about the

* The measurements of the width were taken at top of crown; as, to preserve the parts of the jaw in place, it was necessary to imbed it in plaster.

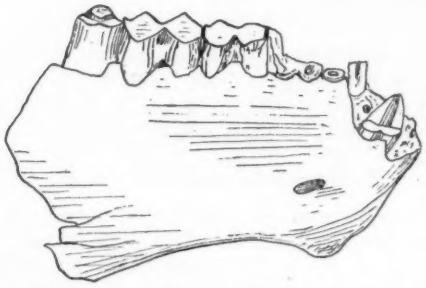
Some teeth overlap a little, so measurements of individual teeth do not quite coincide with the total.

The measurements of depth of jaw are taken from upper projections of bone between lobes of teeth.

same size and shape, but is farther back. The jaw is much deeper and not straight on the lower border back of the chin. It is broken in the region of the incisors, canine and second premolar, but the nearness of the first and third premolars and the position of the lower part of the alveolus of the outside root between these two teeth show that *pm 2* was probably small and closely crowded between them as in *M. compressidens*, to be described later.

On account of the thickness of the ramus and the narrowness laterally of the incisive region there is little curving inward of the inner part posterior to the symphysis.

2



Merycochœrus madisonius, n. sp. × ½.

A low ridge or broad convexity begins just back of *pm 1*, sweeps downward and backward just above the *foramen mentale* to near the lower border of the ramus under *m 1*, then becoming a broad convexity sloping gently laterally it sweeps upward and backward towards the position formerly occupied by the last lobe of *m 3*. It was evidently continuous with the ridge forming the outer anterior border of the ascending ramus.

A cross-section of *pm 1* a little below the alveolar border is rather irregular. Its transverse is much greater than its antero-posterior diameter, the measurements being about 1·5 and ·95^{cm} respectively. The enamel lakes have entirely disappeared in *ms 1* and *2*. In *m 1* the enamel is nearly worn away on the outside. There is only ·4^{cm} left. On *m 2*, 1·25^{cm} of the crown remains, and on the anterior lobe of *m 3*, 2^{cm}. The outer lobes of *m 2* are united as if by a swelling, from each growing together, thus filling up the lower part of the space between them. On the last lobe of *m 2* and the first of *m 1*, the anterior and posterior faces are concave, making the outer lobes contracted in the middle.

Measurements.

Length of lower premolar series, estimated	·049
Length of m 1	·018
Width of m 1	·0155
Length of m 2	·023
Width of m 2	·0134
Depth of jaw at lower border of symphysis	·0585
Depth of jaw under pm 4	·051
Depth of jaw under m 1 middle	·055
Depth of jaw under m 2 middle	·057
Depth of jaw under m 3 anterior lobe	·061
Length of foramen mentale	·0096
Width of foramen mentale	·0026
Thickness of jaw under pm 4, greatest	·023
Thickness of jaw under m 3, anterior part	·0264

Found by myself in the Loup Fork Lake beds, Madison Valley, Montana.

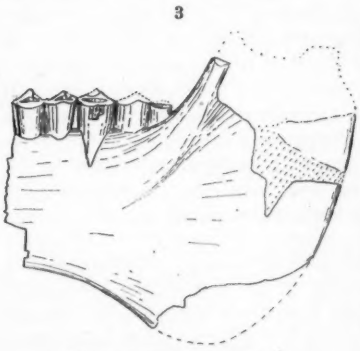
Upper Jaw.—From the same beds as the above is a fragment of an upper jaw with the last three molars, which I refer provisionally to the same species. The part preserved differs from *M. laticeps* in the more posterior position of the inferior border of the anterior root of the zygomatic arch, the lowest part being opposite the anterior part of *m 1*, while in *M. laticeps* it is opposite the last lobe of *m 2*. In the present specimen the posterior border of this root, which forms the anterior border of the zygomatic foramen, is nearly vertical, while in the species above named it slopes backward. The small, short, malo-maxillary ridge extends forward horizontally, quickly dying out on the side of the face above the posterior part of *pm 4*. Above this the surface as far as seen is flat and looks forward and upward. Evidently the face contracted rapidly forward and upward, but its exact shape cannot be told. This sudden contracting would indicate a short skull to correspond with the shortening of the jaw in the type above described. The outer border of the palate next to the teeth is convex antero-posteriorly. The species was smaller than *M. laticeps*. The wearing of the teeth indicates a mature individual. There is a small posterior lobe on the last upper molar as in *M. proprius*, but the median external buttress extends more vertically outward. The other columns were evidently prominent, though they have disappeared.

Measurements.

Length of upper molar series	·072
Length of m 1	·0183
Width of m 1	·022
Length of m 2	·0215
Width of m 2	·021
Length of m 3	·032
Width of m 3	·0268

Merycochœrus elrodi n. sp.

Represented by part of the posterior portion of a left mandibular ramus with the last two molars. This, so far as they can be compared, most resembles *M. madisonius*, but I do not think they belong to the same species. The only portions common to the two are *m 2*, the anterior lobe of *m 3* and the portions of the rami beneath, and here there are no points of exact likeness. In the present species the crowns of the teeth are higher, though this is partly due to a less amount of wear. There is no bridge or buttress uniting the inner lobes in *m 2*. This tooth is longer and narrower in this specimen. There is a cingulum on the anterior face also on the front of *m 3*. The ramus is deeper but not so thick, the difference being more marked near the lower border. The lower border of the jaw is less flat and has an angular ridge near the outside border. The crescent-shaped convexity on the outer face is not seen but under *m 1* the jaw is nearly flat.



Merycochœrus elrodi ×$\frac{1}{1}$.

The contour of the lower border of the jaw differs from that of *M. laticeps*. The descent to form the anterior part of the rounded angle is farther back, and the ramus does not become so deep. The masseteric fossa had evidently about the same position and shape as in *M. altiramus*. A shallow depression or groove extends downward and forward from it to the middle of the jaw under *m 2*. There are traces of a similar groove in *M. Laticeps* and *M. altiramus*.

Measurements.

	M.
M 2, length	·027
M 2, width	·017
M 3, length	·041
M 3, width	·020
M 3, height, about	·030

The name is proposed in honor of my friend Prof. M. J. Elrod of the State University of Montana.

From fragment of indurated clay that had rolled from cliff near top of Big Round Top, east side of lower Madison Valley, about seven miles south of Logan, Montana. Found by the writer.

Merycochœrus compressidens n. sp.

Represented by a left mandibular ramus extending back to beneath *m 3*. The premolars and first two molars are nearly perfect.

The most striking feature of this jaw is the close crowding of the premolars, in all of which there is an overlapping.

The form of the jaw is most like that of *M. proprius*. It differs from all those previously described in this paper, in the narrowness of the horizontal ramus, and from at least part of them in the presence of a first incisor. It agrees with these and differs from the *M. superbus* type including the so-called *M. montanus*, *M. macrostegus* and *M. leidyi* in the crowding with individual lengthening of the premolars, and the less relative length of the series as compared with that of the true molars.

4

Merycochœrus compressidens n. sp. ×¼.

As the mandible is quite thick in the region of the chin, the symphysis is broad, especially the lower half. In *M. madisonius* the broadest part is near the top. Back of the chin the ramus is thinner, then it thickens under the last two molars, partly by the bellying inward on the inside, making a large convexity which stops short of the lower border of the jaw. This convexity is bounded infero-posteriorly by the inner fossa. The molar-premolar series is not straight, but somewhat sigmoid, there being a slight curve inward, outward and inward again in passing backward from *pm 1*. The last two molars form a slight angle with the premolars.

There is a broad protuberance at the angle of the chin. Back of this, the lower border is nearly straight, as far as preserved. The mental foramen is small and nearly round.

All of the teeth were closely crowded. The incisors were laterally compressed. The canine is nearly circular in section. *Pm 1* is quite large but not high. There is an anterior inner angle and a posterior outer one. Between these the tooth is broadly convex, being nearly semicircular in front, and less prominently convex behind. *Pm 2* is more nearly transverse than in a line with the dental series. While its longitudinal diameter is 1·6^{cm}, it occupies only one-half that amount of space on the alveolar border. *Pm 3* is also inserted diagonally but not so much so as *pm 2*. In *pm 4* the posterior part is proportionally broader than in *M. proprius*. The fold of enamel which separated the posterior lobes has by wear become an enamel lake. It occupied the same position as in *M. laticeps*. *Pm 2* has much the form of the corresponding tooth in *M. proprius* except that the anterior lobe has been twisted inward and backward. The same is true of *pm 3*, but on the posterior inner side a little rounded lobe has been added. This is true also of *pm 4* but the lobe is larger.

Measurements.

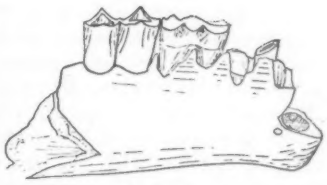
	M.
Length of ramus to second lobe of m 3	·128
Length of three lower incisors	·010
Length of premolars and first two molars	·092
Length of premolar series	·051
Length of ms 1 and 2 and anterior lobe of m 3	·055
Length of canine, about	·009
Width of canine	·009
Length of pm 1	·012
Width of pm 1	·014
Height of pm 1	·023
Length of pm 2	·016
Width of pm 2	·008
Height of pm 2, crown only	·0125
Length of pm 3	·017
Width of pm 3	·011
Height of pm 3	·011
Length of pm 4	·019
Width of pm 4	·014
Height of pm 4	·012
Length of m 1	·018
Width of m 1	·0155
Height of m 1, crown on outside	·0054
Length of m 2	·024
Width of m 2	·0187
Height of m 2	·015
Height of m 3, middle lobe, about	·020

From Loup Fork beds, on east side of Lower Madison Valley. Found by Earl Douglass.

Merycochœrus? obliquidens?

In the collection from the Madison Lake beds are two portions of mandibles of a smaller animal than any of the preceding. One is part of a right ramus containing only one perfect tooth—the first molar. It seems to be much like the one described by Cope as *M. obliquidens*. The ramus is small, narrow and thick. *Pm 1* as indicated by the large abrupt bottom of the alveolus was robust. *Pm 2* was placed diagonally between *pms 1* and *3* as in *M. compressidens*, only more transversely as the alveoli are nearly at right angles to the long axis of the jaw. Evidently *pm 3* was also inserted obliquely, as the anterior root is near the inner margin while the posterior one invades the outer. *Pm 4* was in line with the long axis of the jaw. In the other specimen the fourth temporary premolar is preserved. It has three lobes of which the posterior is slightly the larger. *M 1* has a high, prismatic crown. All the premolars were large. The mental foramen and posterior of symphyseal suture occupy nearly the same place as in Cope's *M. obliquidens*. It is very doubtful whether this belongs to the genus Merycochœrus.

5



Merycochœrus obliquidens?, × ½.
Last premolar from another specimen.

Measurements.

	M.
From posterior of pm 1 to anterior of m 1	·0575
Length of pm 2 at alveolar border	·011
Shortest distance between pm 1 and pm 3	·0055
Length of pm 3 alveolar measurement	·016
Length of pm 4	·0217
Length of m 1	·019
Width of m 1	·015
Height of crown of m 1 outside	·015
Depth of ramus under pm 2 about	·032
Depth of ramus under m 1	·029

As the above described species are represented by portions of mandibles and the most striking differences are in the depths of the horizontal rami, I give below a table which will show the variation in this respect:

Species.	Depth of ramus under						
	Pm2	Pm3	Pm4	M1	M2	M3 ant.	M3 pos.
	M	M	M	M	M	M	M
Merycochœrus laticeps	·043	·053	·050	·053	·067	·076	·109
M. altiramus	·043		·054	·063	·078	·098	·125
M. madisonius		·052	·051	·055	·057	·061	
M. elrodi					·062	·065	·90
M. compressidens	·050	·048	·045	·045	·044	·047	
M.? obliquidens?	·032	·030	·027	·029			

In the above table the measurements are taken as nearly as possible from the alveolar border at the middle of the last lobe of the tooth, except under *m 3* which is taken beneath the anterior lobe, also the posterior one when present.

As previously stated, the discovery of a complete skull of Merycochœrus shows that those previously described under that name must be divided into two genera, though at present the generic limits cannot be definitely defined. I include provisionally under the genus Merycochœrus, of which *M. proprius* is the type, *M. rusticus*, *M. laticeps*, *M. madisonius*, *M. elrodi*, and perhaps *M. compressidens*, and *M. obliquidens*. Were the skulls of all these found, the genus might have to be divided again. The last two have a much slimmer ramus than the others and *M. compressidens* has a first incisor. With regard to *M. obliquidens*, which Cope does not mention in his "*Synopsis of the Oreodontidæ*," this is doubtful.

I have no wish to supply a generic name for the other species that have been included in this genus, as more experienced workers will, I hope, soon make a thorough study of all the data and material available. But for convenience I provisionally call the other members *Promerycochœrus*, as all with the exception of *Promerycochœrus montanus* are older, and some of the species are perhaps in the direct line of *Merycochœrus*. Instead then of using the names *Merycochœrus superbus*, *leidyi*, *chelydra*, *macrostegus*, and *montanus*, I will use provisionally the terms *Promerycochœrus superbus*, *leidyi*, *chelydra*, *macrostegus* and *montanus* respectively.

Between these two groups as I have divided them there is an easily recognizable difference in the inferior dentition. In *P. montanus* and *macrostegus;* and, judging by the upper dentition in *P. superbus* and *chelydra*, the length of the premolar series nearly or quite equals that of the molar series. The molar series may be somewhat longer in *P. leidyi*. In *Merycochœrus proprius*, *rusticus*, *laticeps*, *compressidens*, *altiramus*, and *madisonius*, the premolar series equals, or is slightly less than the length of the first two molars and the anterior lobe of *m 3*. In the first species it is a trifle more and they decrease in

about the order mentioned. In the last the measurement does not fall short more than half the length of the anterior lobe of *m 3*. The measurements of the first two are taken from Leidy's illustrations.*

In all of these there is more or less crowding of the first three premolars, and *pm 2* is placed obliquely in the jaw. In other respects the mandibles vary so much that we may expect that farther discoveries will show that they do not all belong to the same genus.

With regard to a first incisor I have no proof that it was possessed by any but *M. compressidens*.

* Extinct Mammalian Fauna of Dakota and Nebraska.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Periodic Phenomena connected with the Solution of Chromium in Acids.*—While experimenting upon the behavior of metallic chromium with acids, W. Ostwald has found the action to be sometimes periodical. The evolution of hydrogen is at first slow, then it increases to a maximum, becomes slow again, again increases, and so on. The length of the periods from one maximum to the next is to a certain extent constant, as is also the rapidity of increase and decrease of gas evolution. The author was able to measure the rapidity of action by an apparatus analogous to those used in physiological laboratories for measuring changes in blood-pressure. In this apparatus the gas evolved in a flask was allowed to escape through a capillary tube, so that periodic changes of pressure occurred in the flask as the gas was formed more rapidly or more slowly than it escaped from the capillary tube. The periodic change of pressure is not due to a change in the solution, but to a change in the metal. When two pieces of chromium were placed beside one another, but without touching, in the same hydrochloric acid, the apparatus recorded a curve which was equivalent to the summation of two curves for single pieces. When the two pieces were placed in contact, however, the curve had a form like that produced by a single piece. This behavior is connected with the fact that passive chromium (*i. e.* that which does not dissolve in acids) is made active upon contact with active chromium, for in this apparatus contact with the piece which at the moment is giving off hydrogen more actively instantly causes the other to dissolve more rapidly. Different pieces of chromium did not behave uniformly, but gave curves of different forms. It is interesting to notice that only the chromium from a single fusion gave this periodic behavior. It was found that the addition of certain reducing agents, sometimes even in very small quantities had a very marked effect upon the form of the curves by retarding the action. The addition of a little potassium iodide has this effect, while cyanides, sulphocyanides and formaldehyde give still greater effects in the order in which they are mentioned. Other reagents, such as nitric acid, the lower oxides of nitrogen and bromic acid, accelerate the action, making the periods shorter. Hydrogen peroxide has a retarding action, like the reducing agents. Measurements of the electrical tension between the metal and the liquid showed that the metal is ·1 volt more anodic while rapidly dissolving than while slow action is taking place. The variations in tension form a curve similar to that given by the pressure of hydrogen.

In a subsequent communication Ostwald has described further experiments upon this subject. He has succeeded in obtaining

another sample of chromium which showed fluctuations while dissolving, but in this case the periodic action took place only with particular acid solutions, while with other samples of acid of the same concentration a slow, uniform action occurred. It was finally discovered that the acid solutions which induced periodic action contained a trace of dextrin, derived from cloth bags that had been put into the liquids, and upon adding dextrin to other acids they also gave regular fluctuations. An examination of other carbohydrates and similar substances showed that their action is the more pronounced the higher their molecular weight is. The presence of ·001 per cent of glycogen, ·01 per cent of lichenin, ·1 per cent of inulin, or 1 per cent of raffinose sufficed to produce the effect, while more concentrated solutions of cane sugar, milk sugar and dextrose gave a similar result. Certain kinds of chromium are "self-fluctuating," and an addition of dextrin to these produces irregularity in the hydrogen curve, which is more marked the greater the addition that is made.—*Zeitschr. physikal. Chem.*, XXV, 33; 204. H. L. W.

2. *On Krypton.*—This rare constituent of the atmosphere, which was discovered by Ramsay and Travers, has been further studied by LADENBURG and KRUEGEL. They used for the purpose about three liters of residue left by the evaporation of the greater part of 850 liters of liquid air. Upon conversion into gas this residue occupied 2300 liters, and after oxygen and nitrogen had been removed in the usual manner about 3·5 liters of inactive gas were obtained. The latter was condensed by cooling with liquid air, when it formed a colorless liquid in which floated a small quantity of colorless crystals. The liquid was now raised to the boiling-point and fractions of gas were collected according to the boiling temperature, which rose quickly from —189° to —181·2, where it became nearly constant while about 2·5 liters of gas consisting chiefly of argon were given off; then the temperature rose rapidly to —153° where the last portions of the liquid evaporated. At last there remained a crystalline residue which melted at about —147°, then quickly evaporated and was separately collected. This last fraction showed a strong krypton spectrum in which the lines D_4, 589·9 $\mu\mu$, and 558·1 $\mu\mu$ were very brilliant, while many argon lines, including the whole of the violet end of the argon spectrum, were wholly wanting. It was therefore evident that the product contained very little argon, or only a constituent part of that gas. Compared with oxygen as 32, the density was found to be 58·81 and 58·67. These numbers correspond to the atomic weight if the gas is monatomic. Some of this gas was afterwards condensed by use of liquid air, when the tube containing it became covered with a crystalline layer, but no liquid was formed. A fraction of gas which evaporated last from the crystalline deposit gave a density of 59·01. Ramsay expected that the atomic weight of krypton would be about 80, although his density determination with gas which certainly contained much argon gave an atomic weight of

about 45. The authors believe that the new elements of the air should be placed before group I in the periodic system, so that helium = 4, argon = 39, and krypton = 59 come before lithium, potassium, and copper. It is their opinion that air contains less than 0·00002 per cent of krypton, but if this is so it is evident that the 750^{cc} of liquid air of Ramsay and Travers, in which they discovered the element, must have been previously subjected to a great amount of concentration by evaporation.—*Chem. News*, lxxxi, 205, and lxxxii, 209. H. L. W.

3. *The Combustion of Gases.*—It is well known that sufficient dilution of an explosive mixture of gases with any other gas will prevent explosion. Thus Bunsen found that a mixture of 25·79 per cent of detonating gas (hydrogen and oxygen) with 74·21 per cent of carbon dioxide cannot be kindled, while 8·72 parts of detonating gas and 91·28 parts of oxygen behave in the same way. Such facts are satisfactorily explained by assuming that the dilution lowers the temperature of combustion below the kindling point. S. Tantar calls attention to the fact that where the dilution is made with certain hydrocarbon gases the effect is caused by so little of the latter that the usual explanation is not sufficient to account for it. He found that 11–12 per cent of propylene, $CH_2 : CH . CH_2$, or of trimethylene, $(CH_2)_3$, is sufficient to prevent the explosion of detonating gas, while methane, CH_4, prevents the explosion when present in twice the amount, or 22–24 per cent. He found that when a mixture of 5^{cc} of propylene with 45^{cc} of detonating gas was exploded only a small change of volume, at most a diminution of 5^{cc}, took place instead of the expected disappearance of the detonating gas. If 5 to 15^{cc} more of detonating gas was taken than in the preceding experiment the contraction increased to the extent of this addition. An analysis of the resulting gases showed that propylene was no longer present, and that no noticeable amount of carbon dioxide was formed, particularly when the proportion of gases was such that the limit of combustibility was reached. The oxygen was completely used up in the combustion, so that the mixture of gases consisted essentially of carbon monoxide and hydrogen. It is remarkable that the combustion of propylene does not take place under these conditions until there is just enough oxygen present for its complete combustion to carbon monoxide and water, for 5^{cc} propylene require 15^{cc} oxygen or 45^{cc} detonating gas, which is the smallest amount that will cause an explosion. Methane requires half as much oxygen, and combustion actually takes place upon the addition of 25^{cc} of detonating mixture to 5^{cc} of the gas. The results show a remarkable selection which oxygen exhibits in combining with hydrocarbons in preference to hydrogen. Berthelot's thermochemical principle of greatest work does not apply here, for the reaction $6H_2 + 3O_2 = 6H_2O$ produces more heat than $C_2H_6 + 3O_2 = 3CO + 3H_2O$. It is the author's opinion that the only possible explanation of the phenomenon is that the rapidity of the action of oxygen with

hydrocarbons is much greater than with hydrogen. No satisfactory explanation is given for the curious fact that combustion does not take place at all until sufficient oxygen is present for the complete combustion of the hydrocarbon.—*Zeitschr. physkal. Chem.*, xxxv, 340. H. L. W.

4. *The Combustion of Acetylene in Air enriched with Oxygen.*—Having occasion to use high temperatures, G. L. Bourgerel experimented with acetylene by using it in an ordinary blast-lamp. This gave a very high temperature by means of which nickel or pure gold could be melted with ease. Still higher temperatures being desired, the air used for the lamp was replaced by pure compressed oxygen from a cylinder. The result was surprising from the fact that the flame leaving the blowpipe was exceedingly brilliant. The gases did not mix, but burned only in contact with one another, then, little by little, there formed at the extremity of the central tube of the blowpipe a deposit of carbon which rapidly increased, taking the form of a truncated cone with the base outward. The carbon thus formed was very dense and that at the base of the flame was hard and sonorous, and in some instances sufficiently hard to scratch glass. When examined with a lens the carbon showed a cauliflower-like structure. The curious phenomenon was evidently due to the dissociation of acetylene. As the incomplete combustion when pure oxygen was used was unsatisfactory for the purpose of heating, mixtures of oxygen with air were tried with the result that very hot oxidizing or reducing flames could be produced.—*Moniteur Scientifique; Chem. News*, lxxxii, 187. H. L. W.

5. *The inverse effect of a magnetic field upon an electric charge.*—M. G. Lippman, reasoning upon Maxwell's theory of electric convection, shows by the principle of the conservation of energy that variations in the strength of a magnetic field ought to produce a movement of an electrified body placed in such a field. M. V. Cremieu has put this conclusion to the test of experiment. A charged aluminum disc is supported between the poles of an electro-magnet. The author calculates how much turning effect he should obtain on closing or breaking the circuit of the magnet. He did not obtain any effect, and he concludes therefore that this experiment taken in connection with his previous one on electrical convection (Comptes Rendus, cxxx, p. 1544, 1900) proves that the displacement of an electrified body does not produce a magnetic field along its trajectory.—*Comptes Rendus*. No. 15, p. 578, Oct. 8, 1900. J. T.

6. *Electrical Convection.*—M. V. Cremieu returns to his attack on the experiments relating to the possibility of this effect. He has repeated those of Rowland and Himstet, and shows apparently that the effects observed are not due to the magnetic effect of moving charges, since they can be suppressed by the intervention of a metallic plate.—*Comptes Rendus*, Nov. 12, 1900. J. T.

7. *Unipolar Induction.*—E. Lecher continues his discussion with W. König on the question whether a magnetic pole can

revolve around a conductor carrying a current, and whether the well-known pieces of apparatus in physical cabinets which are supposed to illustrate the revolution represent a true phenomenon. He arrives at the conclusion that Biot and Savart's law, which is interpreted without reference to the position of the leading-in wires, is incorrect, and that the observed rotations are entirely due to the leading-in wires. It is impossible apparently to get rid of the effect of these wires in any of the pieces of apparatus which have been devised. There is however no theoretical ground for the existence of the rotation, since action and reaction are equal. H. Lorberg also discusses the point of contention between Lecher and König, and shows that in his Lehrbuch der Physik he arrived at Lecher's conclusion.—*Ann. der Physik*, No. 11, 1900, pp. 513–529. J. T.

8. *Electron theory of metals.*—The most important paper of the last issue of the Annalen der Physik is that of P. DRUDE on this subject. The author seeks to explain the electric current and its effects in the magnetic field by the hypothesis of the movement of electrons or corpuscles between the atoms of the metals of the conductors. He finds a sufficient amount of agreement with known facts to make the theory plausible, but he points out that it is highly desirable to collect together observations on the four transverse-galvanic and thermo-magnetic effects, together with the thermic, the electric conductivity and the Thomson effect in the same piece of metal, in order to prove his theory.—*Ann. der Physik*, No. 11, 1900, pp. 369–402. J. T.

9. *A simple modification of the Wehnelt interrupter.*—This consists in substituting a steel wire for the positive electrode while the negative electrode consists of a copper wire. Both wires are enclosed in glass tubes, except at the ends.—*Ann. der Physik*, No. 11, 1900, pp. 543–544. J. T.

II. GEOLOGY AND MINERALOGY.

1. *Geological and Natural History Survey of Minnesota, Vol. V. Structural and Petrographic Geology of the Taconic and Archean;* by N. H. WINCHELL, assisted by U. S. GRANT. 4°, pp. 1027, pl. 6, St. Paul, 1900.—It would be impossible in the limits of a brief mention like this to do much more than merely state that this volume contains an enormous mass of detailed observations on and descriptions of the rocks of Minnesota.

The first part, of some seventy-five pages, is by Prof. Winchell, and gives a résumé of his views on the general structure, age, origin, relationships and petrology of the rocks of the State.

The second part, by both authors, covers the detailed study of some three thousand thin sections from every part of the area. The occurrences are so numbered that the descriptions can be referred to their appropriate places in the earlier reports of the Survey. As is already well known, the great mass of this work relates to rocks of the gabbroid family.

The third part embraces such discussions and comparisons as to genesis and relationship as appear to be the result of the foregoing, and may be regarded as the petrographic geology of the State. L. V. P.

2. *Étude mineralogique et pétrographique des Roches gabbroïques de l'État de Minnesota, États Unis, et plus specialment des Anorthosites;* by A. N. WINCHELL. Inaug. Diss., Paris, 1900, 8°, pp. 164, pl. 8.—This work, which is being published in English in a journal devoted to geology, is a very careful, minute and painstaking petrographic examination of a series of the gabbroid rocks of Minnesota. It is accompanied by a series of analyses and a number of general conclusions upon the inter-relations of the gabbroid magmas are brought out. Especially noticeable is the detail and care with which the micro-mineralogy of the component minerals has been worked out. L. V. P.

3. *Les Roches Éruptives des Environs de Ménerville, Algérie;* by L. DUPARC, F. PEARCE and E. RITTER. Mémoires de la Soc. de Phys. et d'Hist. Nat. de Genève, xxxiii, No. 2, 4°, pp. 142, pl. 8.—The region whose eruptive rocks have furnished the subject of this memoir lies about 40 miles east of the city of Algiers. There is an important massif of granite, and in the general neighborhood of this extensive areas of rhyolites (liparites), dacites and andesites. All these are carefully described from the petrographic point of view by the first two authors, with many appended analyses. The collection of the material and the geologic portion of the work is by the last-named author. L. V. P.

4. *The Charnockite Series, a group of Archean Hypersthenic rocks in Peninsular India;* by T. H. HOLLAND. Memoirs Geol. Surv. India, vol. xxviii, pt. 2, pp. 130, pl. 8.—The author states that the name charnockite is intended for local use and convenience alone. Although these rocks are of great age, and have thus lost some of the distinctive features of igneous intrusions, they are nevertheless to be clearly regarded as such, and the author takes great pains to give the evidences on this point with fullness and detail. The nearest equivalents of these rocks among types previously described are found in the group of "pyroxene gneisses." The study of the field relations is supplemented by petrographical and chemical investigations. L. V. P.

5. *Geologische Skizze der Besitzung Jushno-Saoserk und des Berges Deneshkin Kamen in nordlichen Ural;* by F. LOEWINSON-LESSING. 8°, pp. 257, pl. 9, Dorpat, 1900.—This volume is published in Russian, but a résumé of 87 pages in German will serve to greatly extend its readers among geologists. After a brief description of the region, the Devonian sediments and the gold-placer mines, the main body of the work is taken up with the petrography of the igneous rocks. Several varieties of these are described in detail, the chief interest centering in those rich in lime, iron and magnesia, a group of gabbros, norites, pyroxenites, dunites, etc. Analyses of these rocks are given and there is a general discussion of their magmatic relations. L. V. P.

6. *Some Principles controlling Deposition of Ores;* by C. R. Van Hise. Paper read before the American Institute of Mining Engineers, February, 1900. Author's edition.—Prof. Van Hise divides his paper into two parts, Part I being a consideration of the principles governing ore deposition, while Part II treats of their application to ore deposits. A brief outline of Part II follows. The outer zone of the lithosphere is a zone of fracture, a zone where the rocks under stress break into fissures, etc. The depth to which this zone extends depends upon the nature of the rocks and other considerations, but in no case exceeds 12,000 meters. Below this depth we have a zone of flowage, where rocks are deformed by flowage but do not fracture. The zone of fracture below the level of ground-water is everywhere permeated by water. This water is ever in more or less rapid circulation. Below the zone of fracture there can be practically no circulation. Therefore the first and fundamental premise of the paper is that the greater number of ore deposits are the result of the work of underground water. The second premise is that the material for ore deposits is derived from rocks within the zone of fracture. The chief cause of the circulation of underground water is gravimetric stress. The water descends through the smaller openings in the rocks, and continually seeking the easiest passages rises at last by means of the main fissures. Descending waters are in the main agents for solution; the ascending waters are in the main agents for deposition. After deposition, a second concentration and general enrichment of the upper parts of ore deposits is caused by descending oxidizing waters from the surface. Ore deposits which have their origin in deposition from solution may be of three kinds, (1) deposited by ascending waters alone, (2) deposited by descending waters alone, (3) deposited by ascending waters and concentrated by descending waters. Deposits of the last class are by far the most numerous. W. E. F.

7. *Physical Geography of the Texas Region;* by Robert T. Hill. U. S. Geological Survey, Physiographic Folio No. 3.—The Physiographic folios "are designed chiefly as aids in the teaching and study of physical geography. Folios Nos. 1 and 2 contain general illustrations and descriptions. The present folio is descriptive of a large area which is particularly rich in distinctive physiographic types. The region is divided according to its geographic features—soil, climate, geologic structure, drainage, underground water, and environment for human culture—into six provinces. These provinces are described in detail, with special reference to the large and small topographic features represented. Plains are represented by the greatest variety, and an unfamiliar type—"Bolson Plains"—has many examples here. "Bolsons" are described as "apparently level valleys inclosed by mountains, ordinarily without drainage outlet—they are usually structural and floored with unconsolidated sediments" (page 8).

Ten sheets of "special illustrations" make the descriptions

doubly clear. They include charts showing drainage, rainfall, flora, mineral resources, distribution of population; photographs of valley, plain, cuesta, and mountain types; and 23 special contour maps of topographic features. This folio should be the textbook for the region it covers and a chapter in any general physiographic work. H. E. G.

8. *Field Operations of the Division of Soils*, 1899; by MILTON WHITNEY. U. S. Department of Agriculture, Report 64; pp. 1–198, with 48 illustrations and 11 maps.—The plan of Prof. Whitney is to map the soils of the country on a scale of an inch to the mile and to give them distinctive local names. Mechanical and chemical analyses of the soils are then made in the field and in the laboratory. This information, taken in connection with the climatic conditions of a region, will determine the possibilities of successful cultivation of certain crops. After the character of the soil and the attitude of ground water is known, then the data are at hand for the study of methods to enrich the soil or to adapt it to particular plants. During 1899 field work was done on the alkali soils of the Pecos Valley, New Mexico, on the Salt Lake Valley of Utah, and on the Connecticut Valley soils of Massachusetts and Connecticut. The detail with which the work has been carried through is well shown by the fact that nine distinct soil types are mapped in the Connecticut Valley—each type suited to its own crops and demanding its own style of cultivation. The Agricultural Department considers this the most important agricultural investigation ever undertaken. H. E. G.

9. *Études sur les Minéraux de la Roumanie*, par P. PONI. Pp. 1–137, Jassy, 1900 (Ann. Sci. Univ. Jassy).—Professor Poni has done a service to mineralogists in giving them this excellent summary of the little-known minerals of Roumania. It includes a catalogue of the species identified in the country, briefly characterized, and with a full account of the localities at which they occur. One of the most important of these lies in the crystalline schists of Broscéni in the district of Sucéva, where a considerable number of metallic species have been found. A number of these new analyses are given. Perhaps the most important pages are those devoted to the account of the rock salt deposits which occur on an enormous scale, although at present only developed at four points. The most important of these is at Slanic, where the amount delivered in ten years, down to 1897–8, was nearly half a million tons. The volume adds two new names to the literature of the mineralogy,—namely Badenite and Brostenite.

BADENITE is an arsenide of cobalt, nickel and iron, containing nearly 5 per cent of bismuth. It is found in the valley of Neguletzul, near the village of Badéni-Ungureni in the district of Muscel. It occurs massive with granular to fibrous structure; specific gravity = 7·104; color steel-gray, becoming dull on exposure to the air. An analysis gave:

As	S	Bi	Co	Ni	Fe
61·54	0·27	4·76	20·56	7·39	5·98 = 100·50

This gives a ratio of 2:3 nearly for (Co, Ni, Fe) : (As, Bi, S). The composition is somewhat analogous to that of rammelsbergite, but the latter has the ratio of about 1:2.

BROSTENITE is a hydrated manganite of iron and manganese, analogous to chalcophanite in composition. It occurs in large quantities in the crystalline schists of the region of Brosténi, district of Sucéva. It is compact, friable; of a black color; luster semi-metallic on the fresh fracture but becoming dull on exposure to the air. Treated with hydrochloric acid, chlorine is freely evolved. Different samples yielded somewhat varying results upon analysis; that from the valley of Holda is interpreted as follows:

MnO_2	MnO	FeO	CaO	H_2O	Gangue (SiO_2)
52·40	6·16	11·47	3·05	11·97	14·75 = 99·80

The formula calculated from this is: $2MnO_2.RO + 2H_2O$, where R = Mn, Fe, Ca. For the mineral from Dorna, the formula $6MnO_2.2RO + 3H_2O$ is calculated; and that from Dealul-Ferului, it is suggested, may be a mixture of these. The deposits of manganese oxides have probably been formed by the action of carbonated waters upon manganese carbonate.

10. *Mineralogy;* by FRANK RUTLEY. Twelfth edition, revised and corrected, pp. 240, 12mo. London, 1900 (Thomas Murby).—The fact that this little work is now in its twelfth edition is sufficient indication of the excellent way in which it fills the place for which it was written. Though necessarily brief in its treatment both of the theoretical and descriptive parts, a great deal of matter is brought together in a small space, and much good judgment is shown in the presentation of the whole.

11. *Corundum and the Basic Magnesian Rocks of Western North Carolina;* by JOSEPH OLNEY LEWIS (Bulletin No. 11, North Carolina Geological Survey). Pp. 107, Winston, 1896.—This Bulletin gives an interesting summary of the occurrence of corundum in North Carolina and the various types of rocks, peridotites, pyroxenites and amphibolites, with which it is associated.

III. BOTANY.

1. *Les Maladies et les Ennemis des Caféiers;* by G. DELACROIX. Second edition, pp. 212, 8°, with 50 figures. Paris, Augustin Chollamel, 1900.—The first edition of this work formed a series of articles published in the *Revue des Cultures Coloniales* in 1898–99, which with numerous additions are now issued as a separate volume. Under the head of non-parasitic diseases are treated such subjects as changes due to excess of heat and moisture. By far the greater part of the volume is devoted to parasitic diseases, including both those due to fungi and those due to insects. Of the former the rust, *Hemileia vastatrix*, is the most widely spread and most injurious, and is treated at length by the author. According to Delacroix, the only parts of the world exempt from this disease are the west coast of Africa, New Caledonia and America, including the West Indies. He does not

accept the statement of Hennings' that the disease occurs in Guatemala, but believes that the trouble in that country is due to another cause. The disease known in Venezuela as Koleroga is due to an imperfectly known sooty fungus, *Pellicularia Koleroga.* There are several troublesome diseases of coffee known as leaf-spots, due to attacks of *Sphaerella coffeicola, Stilbum flavidum, Cercospora coffeicola* and *Gloeosporium coffeanum.* Other diseases in Java and Liberia are supposed to be due to Pyrenomycetous fungi, but their effect has not yet been studied in detail. A chapter is devoted to the action of the leaf-lichens belonging to the genus Strigula and the accompanying alga, *Cephaleuros virescens.* The phaenogamic parasites of the genera Loranthus and Clusia attack the coffee as well as other trees in the tropics, causing damage, but cannot be said to cause special diseases. The present volume is a very useful and convenient treatise which will be especially valuable in tropical countries, since the treatment as well as the origin of the various diseases is given in a way rarely found in works treating of diseases beyond the limits of Europe and North America. W. G. F.

2. *Monographie und Iconographie der Oedogoniaceen;* by Karl E. Hirn. Acta Soc. Sci. Fennicae, xxvii, No. 1, pp. iv, 394, pl. 64. Helsingfors, 1900.—Our systematic knowledge of the Oedogoniacae dates from Pringsheim's monograph in 1858, and this was followed by Wittrock's Prodromus in 1874. To the two genera Oedogonium and Bulbochaete treated by them a third genus, Oedocladium, with a single species, was added by Stahl in 1891. In the elaborate and thorough monograph of Dr. Hirn no less than 199 species of Oedogonium and 43 species of Bulbochaete are recognized besides the single species of Oedocladium. This large number of species is not due to the fact that Dr. Hirn is given to species making. On the contrary he is conservative in his treatment, and a comparatively small number of new species have been described and many species have been reduced to varieties. The monograph will be of great value to American geologists, since our species were in a chaotic condition, and Dr. Hirn, who has received material from several American sources, has been able to give us for the first time a clear and accurate account of our Oedogoniaceae. It is to be regretted that of the numerous American species described in Wolle's Fresh-Water Algae, so large a number cannot be recognized with certainty at the present time. *O. pungens* is an interesting new species collected by Ravenel in South Carolina, and *O. geniculatum* Hirn from California, described in Erythea, 1898, is figured for the first time. To *O. Martinicense* Hirn is referred a form included by Wolle in *O. crassum*, and an unnamed species of Wood is referred with doubt to *O. Margaritiferum* Nordstedt and Hirn. Of the Wittrockian species not before recorded in America may be mentioned *O. Magnusii, O. nobile* and *O. nodulosum.* We should also mention that *O. acrosporum, O. Boscii, O. crispum* and *O. Wolleanum*, species much confused in American herbaria, are here clearly distinguished. An introduction,

giving an account of the structure and general character of the order and its literature, and good plates of the different species, give additional value to this admirable monograph. W. G. F.

3. *Ueber Sclerotinia cinerea und Sclerotinia fructigena;* by M. WORONIN, Mem. Acad. Imp. Sci. St. Petersburg, viii, Ser. x, No. 5, pp. 38, pl. 6, in part colored, 1900.—In the present sequel to the series of papers on Sclerotiniae by Woronin, the author gives a full account of his studies and experiments in relation to the two species to which is due the rotting of cherries, apples and other fruits of the order Rosaceae. The rotting in this case, however, is not the ordinary moist rot, but what may be called a dry wilting. In neither species was Woronin able to observe the cosporic stage, but he considers that they belong to the genus Sclerotinia since their conidia are those of that genus, although the disjunctor is less clearly marked. By some writers *S. cinerea* and *S. fructigena* have been considered forms of one species, but Woronin distinguishes the latter species by its larger conidia, which are yellowish and not gray. He withdraws his previously expressed opinion that the conidia are uninucleate, and states that they are multinucleate. *S. cinerea* is the species which has caused serious disease of cherries in many places, while *S. fructigena* causes a disease in apples and pears. These diseases are usually manifested in the fruit, but may attack twigs and leaves. Both species may occur on drupaceous as well as pomaceous fruits or may, at least, be made to grow on decoctions of them, but in nature Woronin believes that in all serious epidemics it is *S. cinerea* which affects cherries and stone fruits, while in the case of apples and other pomaceous fruits the fungus is *S. fructigena.* W. G. F.

4. *On Platydorina, a new Genus of the Family Volvocidae, from the Plankton of the Illinois River;* by C. A. KOFOID. Bull. Illinois State Lab. Nat. Hist., V, 419–440, pl. 28. Dec. 28, 1899.—In this paper the writer supplements his previous notice of the genus Pleodorina by an account of another very interesting member of the Volvox family discovered during his investigation of the plankton of the Illinois River. The new genus Platydorina, represented by the single species *P. caudata,* is one of the most peculiar members of this peculiar family, and is characterized by its horseshoe-shaped coenobium, composed of 16 or 32 cells with three or five prolongations or tails on the posterior end of the coenobium. The cells of the two sides of the compressed and flattened coenobium intercalate so that the flagella are found upon both faces on alternate cells. The different cells are, however, all similar, and the marked polarity of this genus is indicated by the general outlines of the coenobium rather than by a difference in the cells as in some other genera, as Pleodorina. Although the sexual reproduction was not seen, the non-sexual reproduction and the cell structure and arrangement are considered by the writer to indicate its near relationship to Eudorina. At the end of the paper is a key to the genera and species of Volvocidae. W. G. F.

IV. Miscellaneous Scientific Intelligence.

1. *On the Velocity of Seismic Waves in the Ocean.*—Dr. Charles Davison has recently discussed the waves propagated by the Japanese earthquake of June 15th, 1896, the special object being to compare the observed velocity with that calculated from the usual formula, $v = \sqrt{gh}$, where h is the depth of the ocean taken as uniform, in which waves would travel with the same velocity as that of the seismic sea-waves. In this case, the epicenter was located some 240 km. east-south-east of Miyako, at a depth of 4,000 fathoms. The time of occurrence at Miyako and the surface velocity within the disturbed area being given, the approximate time at the epicenter is obtained, which is assumed to be correct within a minute.

The earthquake waves were observed at two stations, where self-recording tide gauges are established,—namely, at Honolulu, and at Sausalito in San Francisco Bay. In the case of Honolulu the first effect was observed after an interval of 7 hours 44 minutes, a small rise of three-quarters of an inch being noted. The disturbance continued for about 48 hours; at one time a group of seventeen small waves, with an average period of twenty-five and a-half minutes, was recorded. At Sausalito, the first crest reached the gauge after an interval of 10 hours and 34 minutes. Here there was a rise of 3·7 inches; later a series of thirty waves, with an average period of six minutes, and a mean distance between crest and hollow of 1·5 inches, were noted. The distance in the two cases was 3,591 and 4,787 miles respectively. From the time-intervals given, the mean velocity to Honolulu is calculated as 681 feet per second, and for Sausalito as 664 feet. The former would give a uniform depth to the ocean between the two points of 14,492 feet; the latter corresponds to 13,778. In the case of the Honolulu line, the depth is very variable, the Hawaiian Islands coming in between the two places; hence any comparison between the observed and calculated depth is more or less unsatisfactory. In the other case the shortest line joining the two points is free from islands, and cuts the sub-oceanic contour lines nearly at right angles. The mean depth aloug this line is more than 17,000 feet, so that the calculated depth of 13,778 feet is only about four-fifths of the measured value. This ratio is the same as that obtained by the author in an earlier discussion, where the calculated depth was 1900 fathoms and the true depth 2420.—*Phil. Mag.*, Dec. 1900, p. 579.

2. *An Old Indian Village.*—An exhaustive account has recently been published by Johan August Udden, of a series of mounds discovered on the west bank of Paint Creek, about a mile and a half south of Smoky Hill river, in McPherson county, Kansas.

It is noted that such prehistoric monuments are relatively rare west of the Mississippi, which is to be explained partly by the fact of the absence of powerful communities, such as were developed, for instance, in more fertile regions to the eastward as in the Ohio valley, and partly because the region has been thus far only imperfectly studied.

The locality here described includes a group of fifteen low mounds, averaging in most cases 125 feet apart or a multiple of this: they evidently represent the dwelling site of an aboriginal village. The mounds are circular in form, with a diameter of from 20 to 25 feet, and none more than three feet high. The locality was carefully searched and numerous relics, chiefly in the line of domestic utensils, bones of animals, etc., were found. There were no buried human remains discovered. A detailed account is given, with numerous excellent illustrations, of the different articles collected: including scrapers, which were very numerous; also pottery and other domestic utensils; arrow-points and spear-heads, also numerous; agricultural implements and tools; finally a few other articles, as catlinite pipes, etc. The most novel thing discovered was a piece of *chain mail*, presumably of European origin, which, it is suggested, may have been derived from the Spanish expedition of Coronado, which passed through this region in 1542.

In regard to the ethnic relations of the people who dwelt here, it seems probable that they were of agricultural habits and belonged to some tribe of the Siouan family. A certain mingling of northern, southern, and western features of primitive industry and art is noted.—*Augustana Library Publications, No. 2*, Rock Island, 1900.

3. *Anleitung zur mikroskopischen Untersuchung der vegetabilischen Nahrungs- und Genussmittel;* von Dr. A. F. W. Schimper. II Auflage, mit 134 Abbildungen; pp. 158. Jena 1900 (Gustav Fischer).—The second edition of Prof. Schimper's "Anleitung" presents in somewhat systematic order the minute description of the more common vegetable foods and food accessories, with particular reference to their microscopical examination. The food analyst is yearly being confronted with the increased necessity of applying the microscope to the detection of adulterations in food; in fact, in many cases chemical methods absolutely fail to give a satisfactory answer to problems involving the purity of food materials. The book here reviewed is intended as a guide for the beginner, and presents the most recent improvements in technique, together with a large number of drawings for comparison with actual specimens. A brief introduction offers suggestions regarding the equipment of a laboratory adequate for the application of the directions contained in succeeding pages. The topics treated include the common varieties of starchy foods, pepper, tea, coffee, tobacco, mustard, cinnamon, vanilla, agar-agar, etc. L. B. M.